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Learning from Vernacular Buildings: Climate Responsive Design Strategies in Yangzi River Delta, China

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Learning from Vernacular Buildings: Climate Responsive Design Strategies in Yangzi River Delta, China

by

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Thesis

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Dedication

This thesis is dedicated to my husband Ye Tian, who has been a constant source of support and love. And to my parents who give me unconditional love.

Acknowledgements

First and foremost, I must thank my advisors Dr. Petra Liedl and Dason Whitsett, who spend so much time on discussing with me and give me continuous guidance and support. I would also like to thank Dr. Steven Moore for his inspiration and coaching all over the last two years. Also, thanks to professor Yuyu Zhang in Zhejiang University, China, who generously supported in early field study. Finally, thanks to the entire faculty and staff in The University of Texas School of Architecture.

Abstract

Learning from Vernacular Buildings: Climate Responsive Design Strategies in Yangzi River Delta, China

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The University of Texas at Austin, 2015

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Vernacular buildings are famous for their climate and site responsive design strategies. In this modern world with highly developed scientific knowledge, we already own a clear understanding of building physics and energy efficient design strategies. There are already lots of generalized observations on vernacular buildings' climate responsive design strategies. However, detailed and reliable measurements and researches on one particular vernacular building really lack, especially vernacular buildings in developing countries.

Hui Style Building is a specific building type in the Southeastern China with more than 1000 years' history. This paper focuses on analyzing its design strategies and all the parameters which influence its energy performance and tries to answer this question: what kind of design strategies derived from vernacular buildings in southeastern China, can be used in modern buildings, to promote climate responsive design?

A typical residential vernacular house in Xinye Village, Zhejiang, China is chosen as the target house. A three-days field study was conducted to measure this building's microclimate by hobo logger. Professor Yuyu Zhang provided detailed drawings of this house for further analysis. With all those information collected, passive design strategies used in this building were simulated and analyzed by ClimateTool and EnergyPlus.

The finding of my research is a thorough report of a typical Hui Style Building. Suggestions of how to combine ancient wisdom with modern building techniques to meet modern living standards were given. The purpose of this thesis is to give contemporary architects guidance and some inspirations for climate responsive design with cultural roots in southeastern China.

Key Words: Vernacular Building, Sustainable Design, Hui Style Building, Energy Efficient Building

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Learning from Vernacular Buildings

Vernacular buildings have a reputation of cooperating with climate to create more sustainable buildings. That's one of the reasons that contemporary architectural community always has strong interests in traditional vernacular buildings. The earlier researches and publications on vernacular buildings are mostly following an anthropological or archaeological approach. As what is mentioned in book "Lessons from Vernacular Architecture": generalized observations on the climate adaptation of vernacular buildings are plentiful, but detailed and reliable measurements are quite scarce (Weber and Yannas 2013). This book also suggests that there are two important ways in which vernacular architecture continues to be of direct and practical interest for contemporary architects today. First, we can learn the application of passive techniques, which interactively combine the building's architecture and inhabitant's lifestyle. Secondly, vernacular architecture also has the capacity to inspire the development of new ideas and projects for contemporary architects. It is an inspiration rather than limitation.

The objective of this thesis is to do detailed researches on one particular vernacular building, Hui Style Buildings in southeastern China. It focuses on Hui Style Buildings' physical relationship with climate and site. A typical Hui Style Building is chosen and thoroughly studied by detailed analysis of its building elements and components.

1.2 Hui Style Building

Hui Style Building is one of the major Chinese architectural styles of ancient times. Most of Hui Style Buildings are located in Yangzi River Delta Area, southeastern China, which has a subtropical mild and moist climate. Hui Style Buildings are always built with black tiles and white walls, surrounded by high walls shaped like horse heads. Courtyard inside this building helps to reduce the beat of sunshine and enjoy natural ventilation. They are always decorated with artworks made of brick wood and stone. This kind of vernacular building is harmonized with refined and elegant colors and brings us a strong sense of beauty.

Chapter 2: Literature Review

Vernacular architecture is famous for its climate and site responsive design strategies. As what Amos Rapoport states in his influential book House Form and Culture: there is “amazing skill shown by primitive and peasant builders in dealing with climatic problems, and their ability to use minimum resources for maximum comfort”(Rapoport 1969).

In this modern world with highly developed scientific knowledge, we already own a clear understanding of building physics and energy efficient design strategies. On the way of pursuing more climate responsive architecture, what can we learn from vernacular architecture? Papers collected in Lessons from Vernacular Architecture show that there are two important ways in which vernacular architecture can contributes to the modern architecture practice. The first is vernacular architecture “provides a large pool of buildings on which to study the application of passive techniques of environmental design”(Roaf, Fuentes, and Thomas-Rees 2014). Although energy efficient design strategies have become a hot topic in architecture design field, few contemporary building types lend themselves to such studies, especially in developing countries and in warm climates where air conditioners are commonly used. The second aspect, which we can learn from vernacular architecture, is its cultural values. Le Corbusier once stated, “…tradition is the unbroken chain of all renewals and, beyond that, the surest witness of the projection toward the future”(Corbusier 1957). Vernacular architecture is architects’ inspiration for new ideas and projects. It acts “as a springboard and model for innovation rather than imitation”(Roaf, Fuentes, and Thomas-Rees 2014).

French philosopher Paul Ricoeur once asked "how to become modern and to return to sources; how to revive an old, dormant civilization and take part in universal civilization"(Frampton 1993). Theorists of critical regionalism aim to answer this question in architecture field by rethinking architecture through the concept of region. Tzonis and Lefaivre in Tropical Architecture: Critical Regionalism in the Age of Globalization maintain: "Critical regionalism should be seen as complementary rather than contradictory to trends toward higher technology and a more global economy and culture. It opposes only their undesirable, contingent by products due to private interests and public mindlessness"(Tzonis, Lefaivre, and Stagno 2001). Kenneth Frampton, who goes deeper in this topic, states in Towards a Critical Regionalism: Six points for an architecture of resistance, that critical regionalism should adopt modern architecture, critically, for its universal progressive qualities but at the same time value should be placed on the geographical context of the building. He states that emphasis should be on topography, climate, tectonic form and sense of touch (Frampton 1993).

Some researches about how vernacular technologies, materials and forms may be applied in contemporary design have already been done. Zhiqiang et al. (Zhai and Previtali 2010) introduced an approach to categorizing distinct vernacular regions and evaluation energy performance of ancient vernacular homes as well as identifying optimal constructions using vernacular building techniques. Manioğlu and Yilmaz(Manioğlu and Yılmaz 2008) studied energy saving design strategies used in vernacular house in Mardin, Turkey. They made a simplified thermal evaluation and comparison of a traditional house with a contemporary house by using in-situ measurement and questionnaires, which were carried out in 100 buildings. They found traditional house perform better than the contemporary house in indoor thermal comfort and energy saving. In an intensive study in Japan, Hiroshi(Yoshino, Hasegawa, and

Matsumoto 2007) researched four traditional farmhouses using both field measurement and computer simulation on a model house. The finding reveals that cooling technologies of traditional buildings are effective for interior cooling.

This paper applies the theory of critical regionalism to the study of Hui Style Buildings in YRD in the east of China. The purpose of this study is to give contemporary architects a comprehensive understanding of Hui Style Buildings physic aspects to promote climate and cultural responsive design. There will be four categories in my literature review: “define vernacular architecture,” “learn from vernacular architecture,” and “vernacular architecture’s physical relationship with climate and site”. The first two categories build a theoretical view of what is vernacular architecture and what we can learn from it. Articles in the third category introduce some methods of vernacular architecture’s physical properties’ measurements.

Chapter 3: Simulation Method and Model Information

3.1 Simulation Software

There are two simulation software used in this research: EnergyPlus and ClimateTool. EnergyPlus is an energy analysis and thermal load simulation program. "Based on a user's description of a building form the perspective of the building's physical make-up and associated mechanical and other systems, EnergyPlus calculates heating and cooling loads necessary to maintain thermal control set points, conditions throughout a secondary HVAC system and coil loads, and the energy consumption of primary plant equipment. "(EERE 2015) In this paper, EnergyPlus was used to explore indoor climate, heating and cooling loads and illuminance map in target house.

ClimateTool is an easy-to-use planning tool developed by Professor Petra Liedl. "ClimateTool allows the analysis of the climate relevant aspects in planning, namely temperature, humidity, solar radiation, light and wind and the presentation of results in performance tables for any given location on earth. The analysis shows the challenges and potentials of each location worldwide as well as the relevance of the individual climate elements." (ClimateTool 2015) In this research, ClimateTool was used to analyze the urban context of target house and passive design strategies, which can be used in this climate.

3.2 Target House Introduction

Figure 1: Xinye Village, Zhejiang, China.

Figure 2: Yiyangtang, Xinye Village, Zhejiang, China.

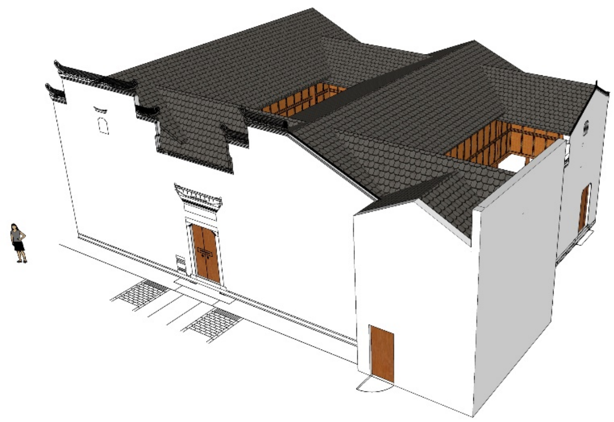

Figure 3: SketchUp Model of Yiyangtang, Xinye Village, Zhejiang, China.

The chosen target house (Fig. 2) is located in southeastern Xingye Village (Fig.1), Zhejiang Province, China. Xinye village is a historic Chines village with more than 800 years history, which is known for its well-preserved Ming and Qing era architecture and ancient residential buildings. First built in the end of Ming dynasty, the target house (Fig. 2) has about 500 years history. It is a typical residential house of a middle class family in this village. This house's Chinese name is Yiyangtang, which is very poetic with the meaning of "living harmoniously with birds". In 1990s, people changed it into a rice wine museum.

This target house has two floors. On the first floor, there is a kitchen, a dining area, and some public spaces. Only the kitchen is an enclosed space. Other spaces are open to the inner garden and have no inner facing walls. On the second floor, there are six bedrooms and some storage spaces. Most of the windows are open to the inner courtyard. Only a few small windows are open to the public areas. The arrangements of these spaces are quite flexible.

3.3 EnergyPlus Model Information

The purpose of this research is to study target house's physical relationship with climate and site. To make the simulation results more reliable, I was trying to reveal the ancient lifestyle happened there. Assumptions of occupancy schedule are made based on observations of families in this village.

3.3.1 Occupancy Schedule

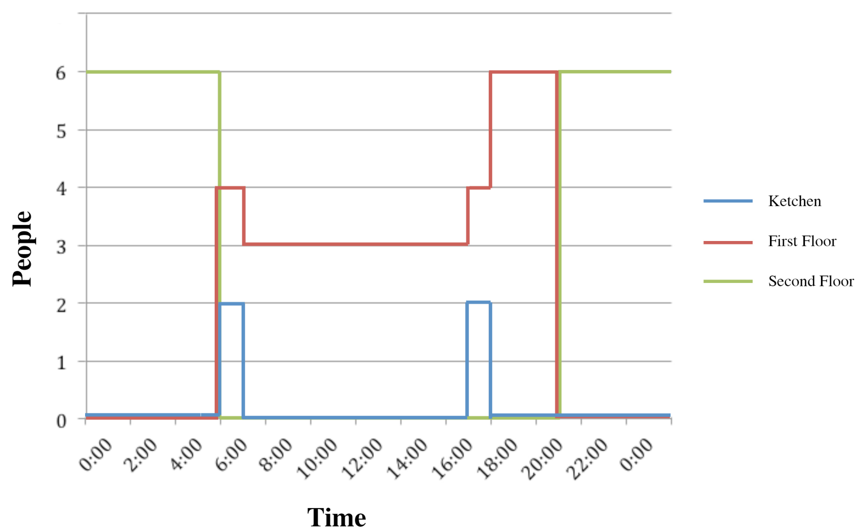

Figure 4: Occupancy Schedule in 3 Zones.

In the EnergyPlus model, six people live in this house and have the same schedule every day of the year. Everyone sleeps in the "second floor" and wakes up at 5am. Two occupants go into the "kitchen" and cook breakfast. The other four go to the "first floor". At 7am, three users leave for the day and three remain in the "first floor" until 5 pm. At that time, the other three persons return home and everyone spends the time on cooking/chatting until 8pm in the “first floor”. At 8pm everyone goes to bed in the “second floor” zone.

3.3.2 Zones Definition

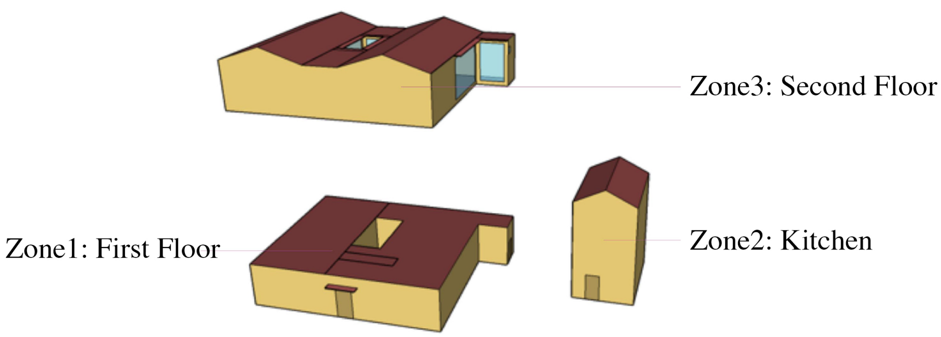

Figure 5: 3 Zones in IDF model.

There were three zones in target house’s EnergyPlus model: First Floor, Second Floor and Kitchen (Fig. 4). There is no HVAC system in free running target house model. In another simulation model, second floor will be conditioned to calculate its heating and cooling loads.

3.3.3 Activity Level Definition

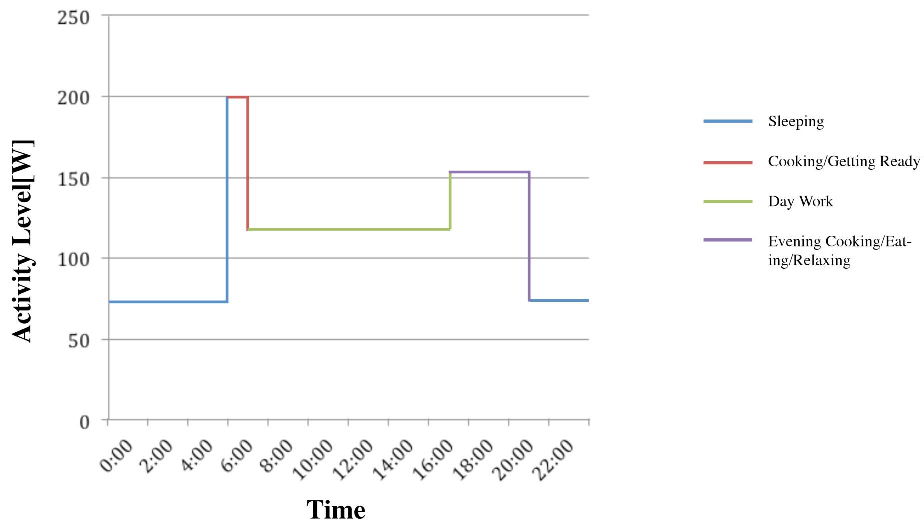

Figure 6: Activity Levels in Target House.

Activities happen in this are defined as below:

- Sleeping: 72W
- Cooking/Getting ready: 200W
- Day work: 120W
- Evening cooking/Eating/Relaxing: 154W
- People: assume 0.5 for the radiant fraction for people.

3.3.4 Heating and Cooling Schedule

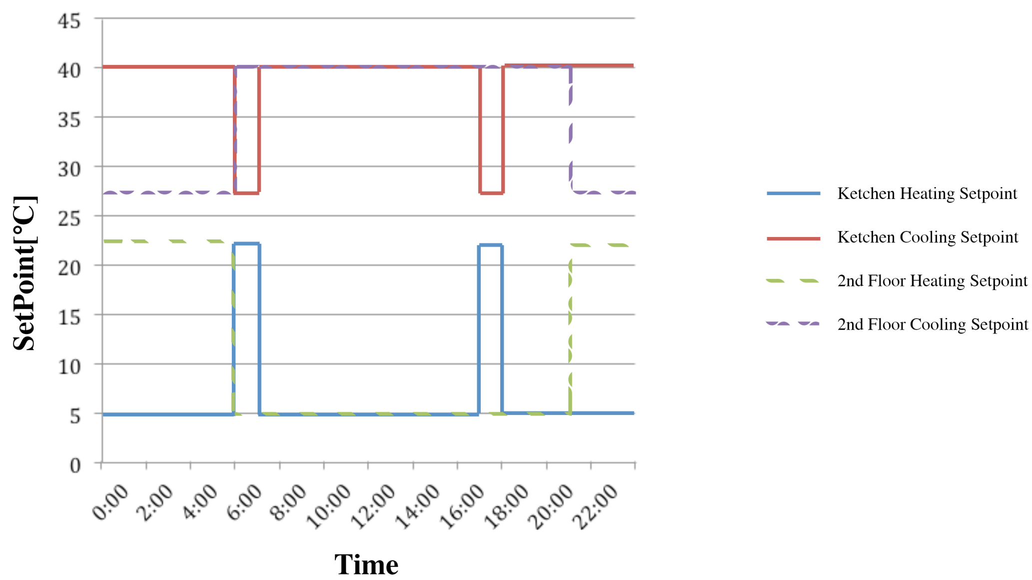

Figure 7: Heating and Cooling Schedule.

In order to calculate heating and cooling loads of this building, a simplified HVAC system was built in one of the EnergyPlus models. The cooling set point is 27 ºC, while the heating set-point is18 ºC. The definition of heating and cooling set point was based on authors' own experience for living in this area for seven years.

3.3.5 Season Typical Days Definition

Season typical days in this simulation were defined to present different seasons in this simulation. Season typical days used in this thesis are defined as below.

- Winter Typical Days: 01/02-01/10
- Summer Typical Days: 07/15-07/23
- Autumn Typical Days: 09/23-10/01

Chapter 4: Field Study and Urban Context

4.1 Macroclimate of Target House

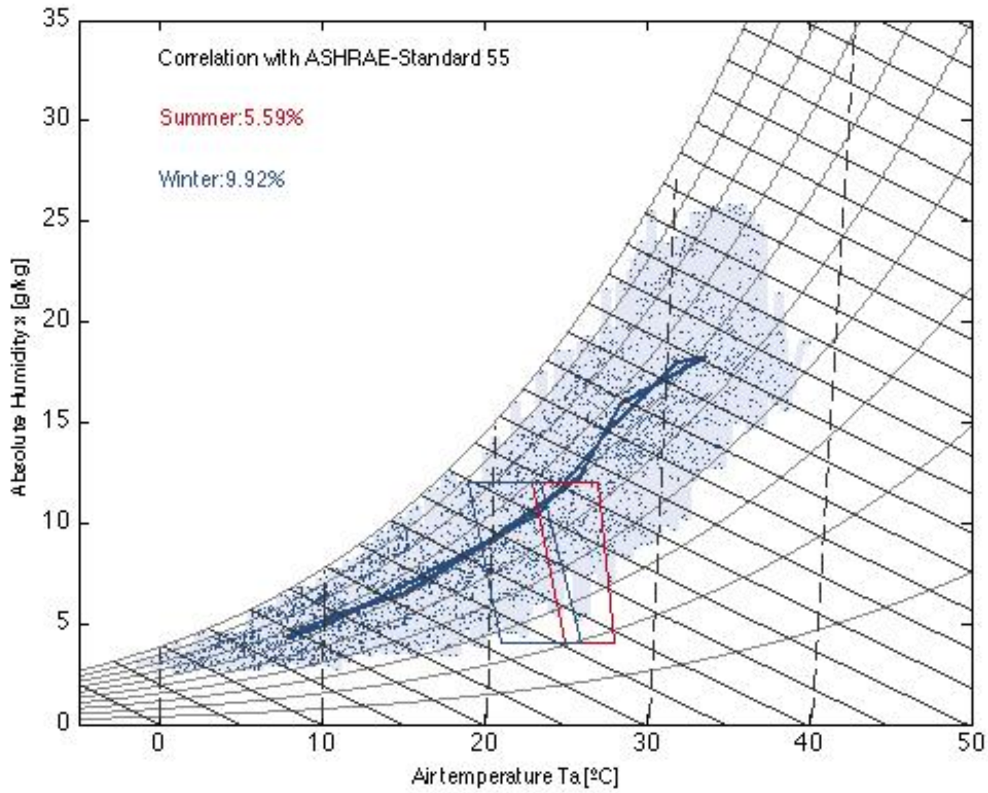

Figure 8: Psychometrics Chart of Xingye Village by ClimateTool.

Xinye Village has a subtropics climate. In book *Building to Suit the Climate*, there is a thoroughly illustration about features of this climate and how it influences buildings. "This climate is characterized by hot and humid or warm summers, and wet and cold or cool winters. The cooling energy demand and the dehumidifying energy demand are the major factors during the summer, particularly in areas in the northern hemisphere and on the east coasts of open oceans. The frequently high outdoor air temperatures and the high absolute humidity restrict window ventilation. Surface cooling systems are affected by dew point issues. Window ventilation is possible during transitional times, particularly in high latitudes. In areas outside the tropics, the heating energy demand is low during the winter, and the humidifying energy demand is almost non-existent. The extent of the energy demand cannot be established with any certainty simply by looking at the location."(Liedl, Hausladen, and Saldanha 2012)

4.2 Microclimate of Target House

4.2.1 Hobo Logger Measurement

Temperature hobo logger is a temperature recorder for use in a wide range of applications. It can automatically document temperature and relative humidity in a surrounding environment. To have a better understanding of the microclimate in this building, I spent three days (from 5/15/2014 to 5/18/2014) in this village and used four hobo loggers (table 2) to measure the microclimate in this house. These microclimate data will also be used to testify the accuracy of simulation data in the upcoming chapter.

No.	Description	Capability	Location
Hobo1	HOBO UX100-003 Temp/RH data logger	Records temperature and relative humidity (within 3.5% accuracy)	Entrance
Hobo2	HOBO U10 Temp Logger	Records indoor temperature	Lobby
Hobo3	HOBO U10 Temp Logger	Records indoor temperature	Restroom on Second Floor
Hobo4	HOBO UX100-003 Temp/RH data logger	Records temperature and relative humidity (within 3.5% accuracy)	Outdoor environment

Table 1: Hobo Logger Information.

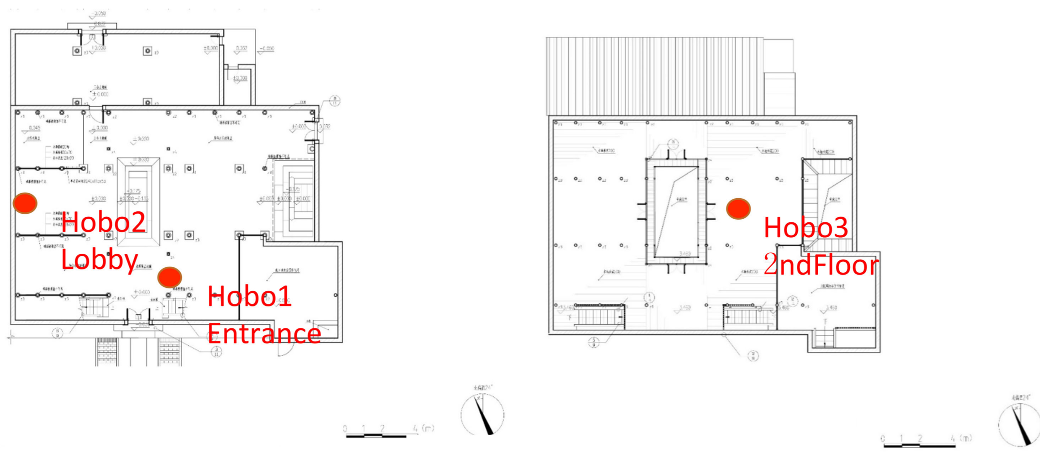

Figure 9: Hobo Logger Location.

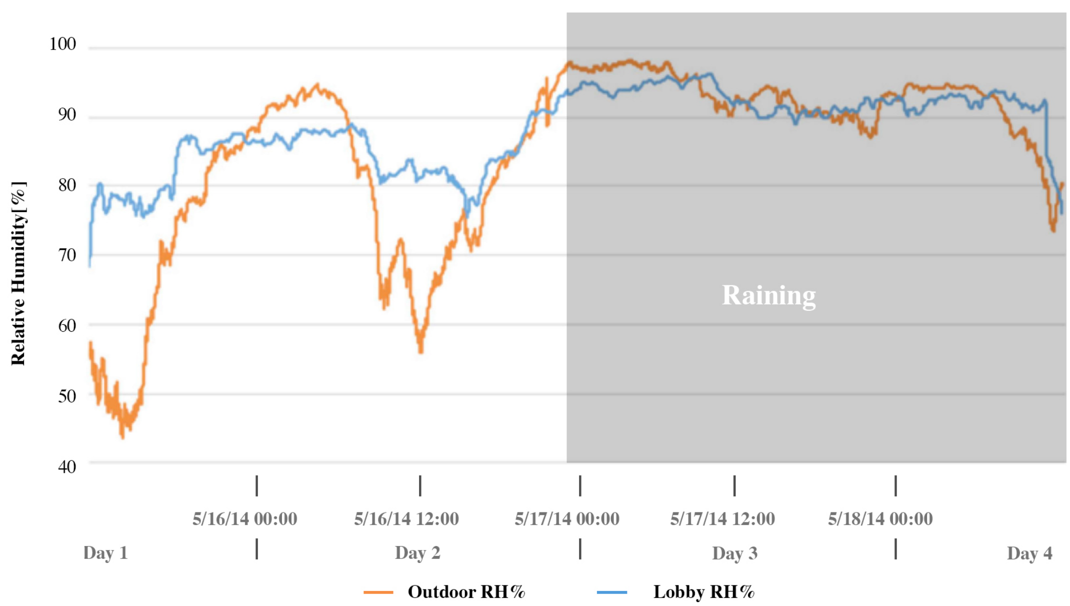

Figure 10: Relative Humidity of Target House by Hobo Logger.

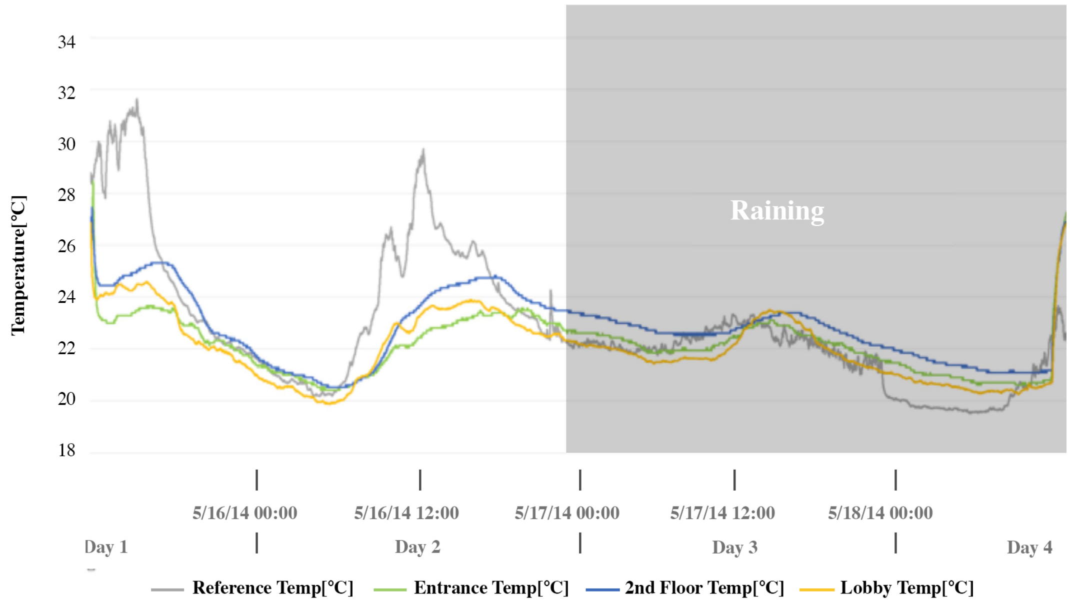

Figure 11: Temperature of Target House by Hobo Logger.

Hobo1 and Hobo4 can both document temperature and humidity, while Hobo2 and Hobo3 can only sense the temperature. Hobo1 was placed in the entrance of this building and Hobo2 was placed at an outdoor shaded place. Hobo4 was used to document the outdoor climate. At the same time, Hobo2 and Hobo3 were installed at lobby and a living room on second floor (fig. 5).

From the diagram above, we can see that the indoor temperature has less fluctuation. This building effectively prevented the indoor environment getting too hot in this early summer. However, in this humid climate, as the first floor is totally open to the outdoor environment, this target house is not effective in reducing the level of humidity

4.2.2 Conclusion

The purpose of this field study is to get an idea about the performance of the target house. The microclimate data show that the house is quite efficient in keeping a pleasant temperature, while, in this humid climate, it’s really hard for a passive building to dehumidify its indoor air and meets the modern standard for comfortable humidity level. However, according to my own memory, the most memorable moment during my living experiences in this building was, when I was breathing in the warm and humid fresh air in the courtyard after rain. People living in this climate have a better tolerance with the humidity level. Understanding this is very important for contemporary architects. Sustainability is not just about to fulfill the criteria and modern definitions for green buildings. Understanding the culture and local people’s life style is also helpful.

4.3 Urban Context

4.3.1 Xinye Village

Figure 12: Google Map of Xingye Village.

Figure 13: Narrow Street in Xinye Village.

Figure 14: Public Spaces in Xinye Village.

Xinye Village is a well-preserved historical village. There are more than 200 residential vernacular buildings in this village. Houses are connected by very narrow streets and some neighbors even share the same wall. A typical street in this village is about two to three meters wide. The majority of windows are facing towards the inner yard. Only a few small windows are facing public area. Natural light and ventilation are introduced into this building mainly through inner yard. Public spaces of different sizes are separated in this village.

4.3.2 Wind

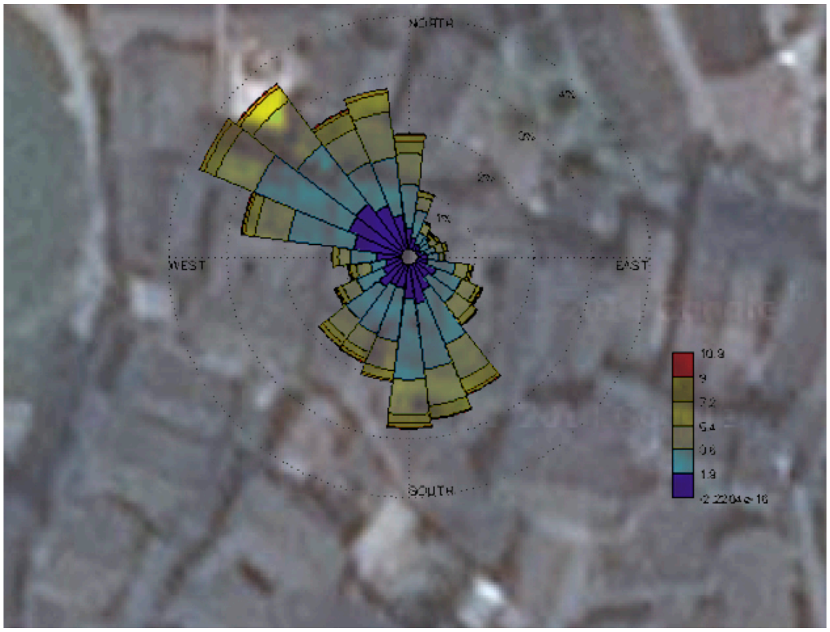

Figure 15: Year Day Wind Rose.

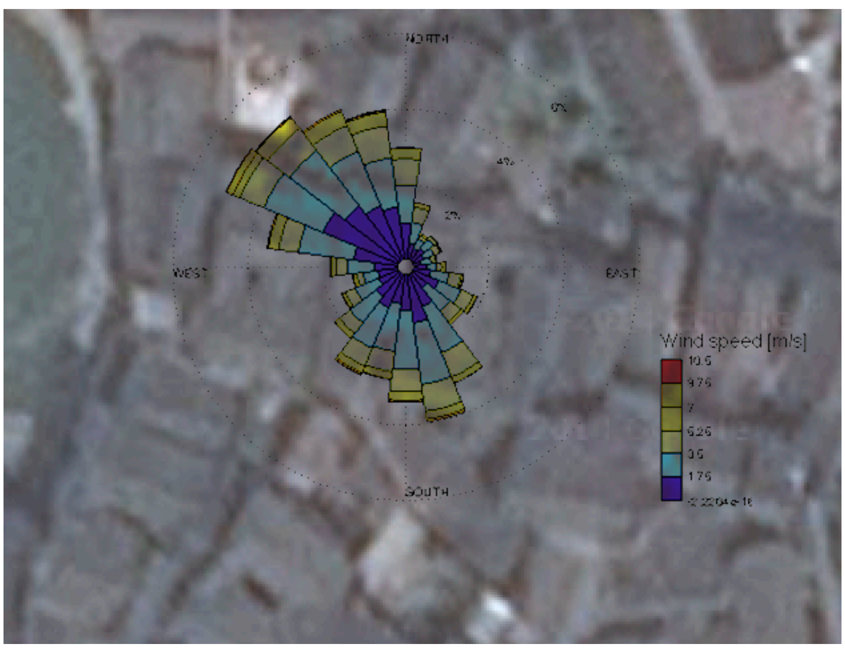

Figure 16: Year Night Wind Rose.

The wind rose shows that wind in this area mainly comes from the Northwest. Most of the time, wind speed is below 9 m/s, which can be defined as “moderate” for strolling in this dense urban context (Blocken, Janssen, and van Hooff 2012). Wind is moderate in this area.

4.3.3 Solar Radiation

Annual electricity demand	4400	kWh/a
Solar area	100	m^2
PV-efficiency factor	0.2	
Heat pump [power/COP]	3 / 4	kW / _
Glazing sunshading	90	%
Cooling when ø temp. day >	18	°C
Heating when ø temp. day <	12	°C
Air change rate (Night/Day)	0.5/1	1/h
Chiller [power/EER]	3 / 3.2	kW / _

Figure 17: Solar Balance Setting.

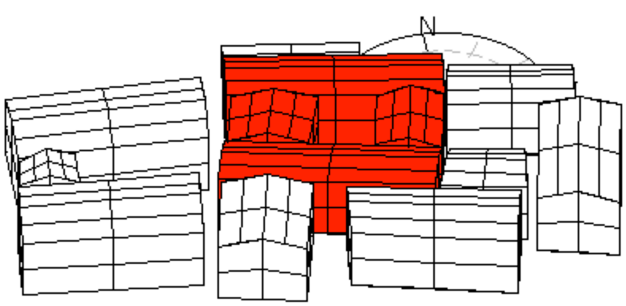

Figure 18: ClimateTool Model.

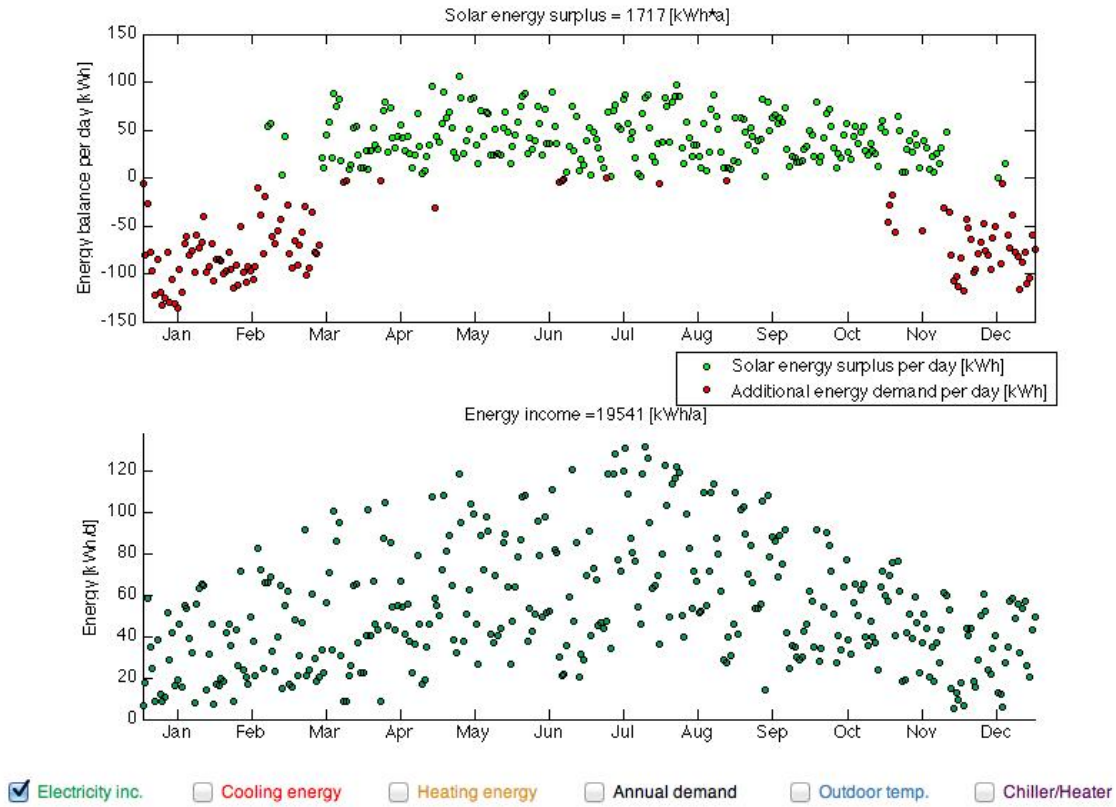

Figure 19: Solar Energy Balance.

Boundaries:

- Emission coefficient: 0.9
- Absorption coefficient: 0.3
- Heat transfer coefficient external wall: 50 [W/m^2K]
- Heat transfer coefficient internal wall: 10 [W/m^2K]
- Target temperature inside: 23 [C]
- U-value wall: 0.2 [W/m^2K]
- Glazing percentage: 40%
- U-value glazing [W/m^2K]: 0.90

To have a better understanding of solar radiation in this area, ClimateTool was used to estimate energy balance for this building. The estimated annually electricity demand is 4400 kWh and the defined solar area is 100 m2. Simulation shows that from March to November, solar energy can fulfill this building's energy demands. Only in a few months, extra energy is needed.

Chapter 5: Material and Construction Research

5.1 Original Material Analysis

5.1.1 Original Material Introduction

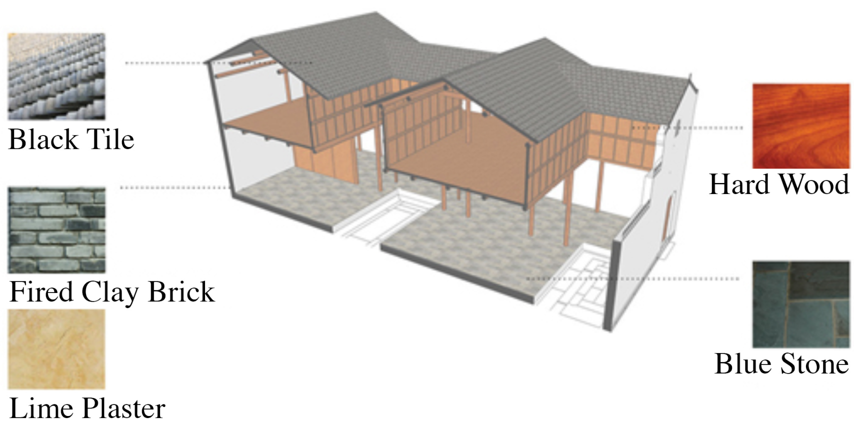

Figure 5: Original Material Used in Target House.

In book “Green building materials: a guide to product selection and specification”, green building materials were defined as: “those that use the Earth’s resources in an environmentally responsible way. Green building materials respect the limitations of non-renewable resources such as coal and metal ores. They work within the pattern of nature’s cycles and the interrelationships of the ecosystems. Green building materials are nontoxic. They are made from recycled materials and are themselves recyclable. They are energy-efficient and water-efficient. They are green in the way they are manufactured, the way they are used, and the way they are reclaimed after use."(Spiegel and Meadows 2010)

Conventional materials used in this house are timber, fired brick, black tile and stone. They are all local materials with therefore relatively low energy in transportation. However, not all the conventional materials are suitable for contemporary buildings. For example, the burning of fuel for firing bricks will result in emissions of gaseous pollutants and ash into the environment.

Timber:

In this target house, except for the exterior walls and roof, almost all the other structure is made of wood. Wood is a natural and environmentally friendly material. Increasing wood recycling offers the possibility to enhance the resource efficiency of wood (Goverse et al. 2001).

Fired brick:

Traditional masonry in the east of China mainly use fired clay bricks. The firing process can take hours or even days and requires a large amount of energy. According to Reddy and Jagadish (Reddy and Jagadish 2003), fired-clay brick masonry has an energy that is almost 300% higher than the energy of concrete block masonry.

Black tiles:

Black tiles used for traditional Hui Style Buildings are made by fired clays. It also costs lots of energy in manufacturing process, which is against the sustainable building criteria.

Stone:

Eastern China has rich stone resources. That's why stone are commonly used in Hui Style Buildings. Stone is a great natural material and has excellent thermal properties, which is beneficial for building's indoor comfort. However, the cost of the stone is relatively high for contemporary buildings.

5.1.2 Sustainable Building Material Criteria

Professor Kim Jong-Jin and Brenda Rigdon presents "three groups of criteria, based on the material life cycle, that can be used in evaluation the environmental sustainability of building materials."(Kim and Rigdon 1998). The chart below introduces these criteria. It can help to compare the sustainable qualities of different materials used for the same purpose. The presence of one or more of these "green features" in a building material can assist in determining its relative sustainability.

Green Features

Manufacturing Process (MP)	**Building Operations (BO)**	**Waste Mgmt. (WM)**
Waste Reduction (**WR**)	Energy Efficiency (**EE**)	Biodegradable (**B**)
Pollution Prevention (**P2**)	Water Treatment & Conservation (**WTC**)	Recyclable (**R**)
Recycled (**RC**)	Nontoxic (**NT**)	Reusable (**RU**)
Embodied Energy Reduction (**EER**)	Renewable Energy Source (**RES**)	Others (**O**)
Natural Materials (**NM**)	Longer Life (**LL**)	

Figure 21: Key to the Green Features of Sustainable Building Materials.

5.1.3 Target House's Material Evaluation

Below is the checklist of traditional materials' green features according to Professor Kim Jong-Jin and Brenda Rigdon's green building criteria. From this chart, we can conclude that: some of the traditional materials are not able to achieve the criteria for sustainable materials. For contemporary architects, learning from vernacular doesn't mean that we should use exactly the same material as the vernacular buildings. In old times, people are much more isolated than in the modern world. They tended to make the maximum use of local resources, which reduces the embodied energy of materials during transportation. However, learning from vernacular doesn't mean to refuse to accept the changing of the world and take advantage of new technologies. With a better understanding of materials and sustainable material criteria, we can make a smarter choice.

	Manufacturing Process					**Building Operations**					**Waste Management**		
	WR	P2	RC	EER	NM	EE	WTC	NT	RES	LL	B	R	RU
Wood	√	√	√	√	√	√		√	√	√	√	√	√
Fired Brick			√							√		√	√
Black Tile			√							√		√	√
Stone			√		√			√	√	√	√	√	√

WR: Waste Reduction
P2: Pollution Prevention
RC: Recycled
EER: Embodied Energy Reduction
NM: Natural Material

EE: Energy Efficiency
WTC: Water Treatment&Conservation
NT: Nontoxic
RES: Renewable Energy Source
LL: Longer Life

B: Biodegradable
R: Recyclable
RU: Reusable
O: Others

Table 2: Checklist of Green Features of Traditional Materials.

5.2 Indoor Climate Simulation

5.2.1 Introduction

Measuring indoor climate of target house with hobo loggers during three days, which gives us a general view of target house's performance. However, 3 days indoor climate data is not enough for a thoroughly understanding of this building. It is important to have a look at how this house performs in different seasons and during different outdoor climate. To achieve this, a free running EnergyPlus model was built to simulate target house's indoor climate. The definition of this EnergyPlus model has been described in Chapter 3. To verify the accuracy of this simulation, simulated data will be compared with the weather data documented by hobo logger.

5.2.2 Indoor Temperature

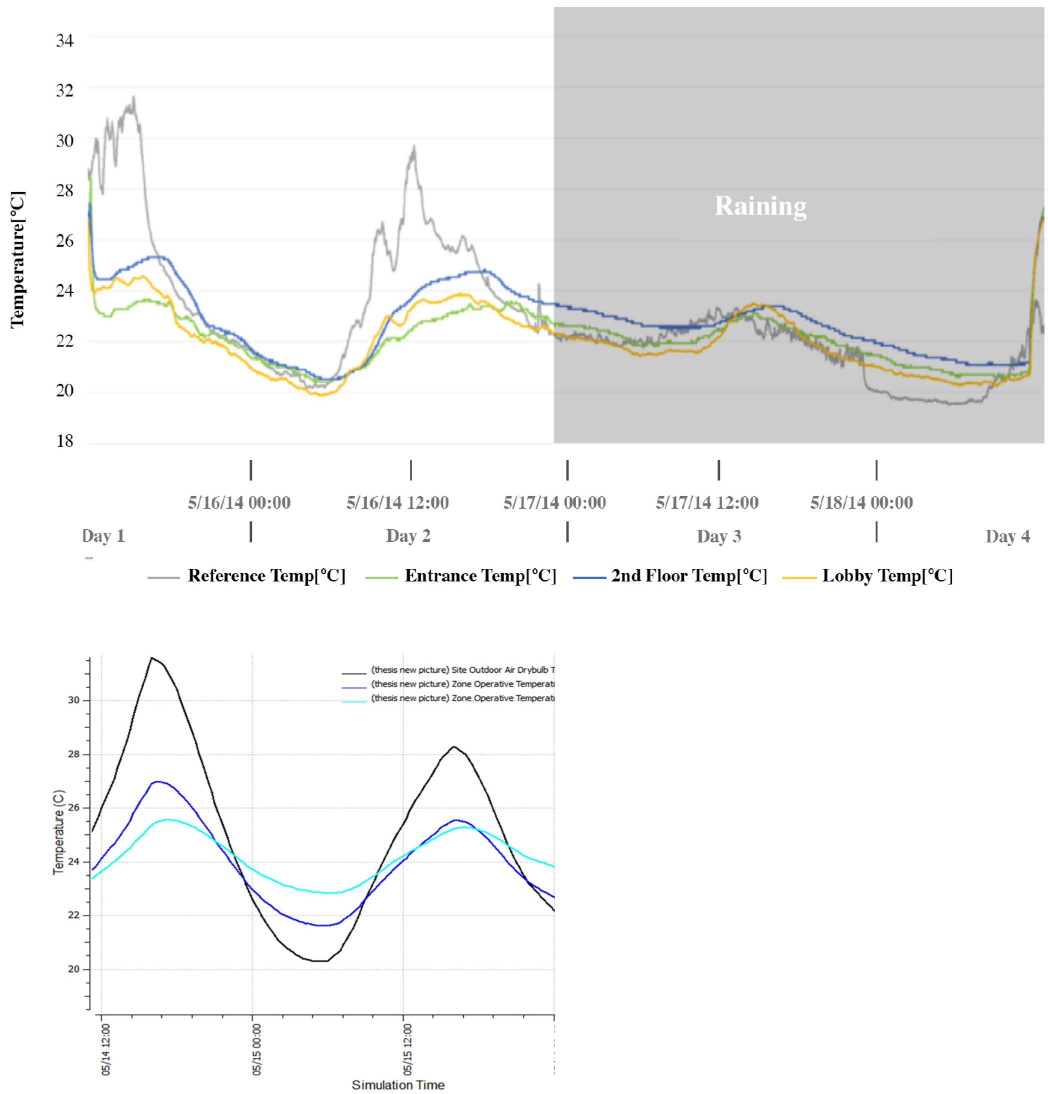

Figure 22: Comparison of Temperature: Hobo Logger Documentation vs. EnergyPlus Simulation.

Hobo loggers documented 3 days temperature in and out of the target houses. As in the last one and a half days it was raining outside, the temperature curve is more flat. For this raining period, there was no similar weather data in the weather file I used. For this reason, only the first 36 hour's indoor and outdoor temperature was compared.

The outdoor temperature range of the first one and a half days documented by hobo loggers is 20-32 °C. The outdoor temperature from 5/14 12:00pm to 5/16 0:00pm in the weather file I used in EnergyPlus is very similar with the one measured by hobo logger. The simulated indoor temperature in the first and second floor also matches well with the measured indoor temperature in first and second floor. According to this comparison, I can tell that the simulation results are quite reliable.

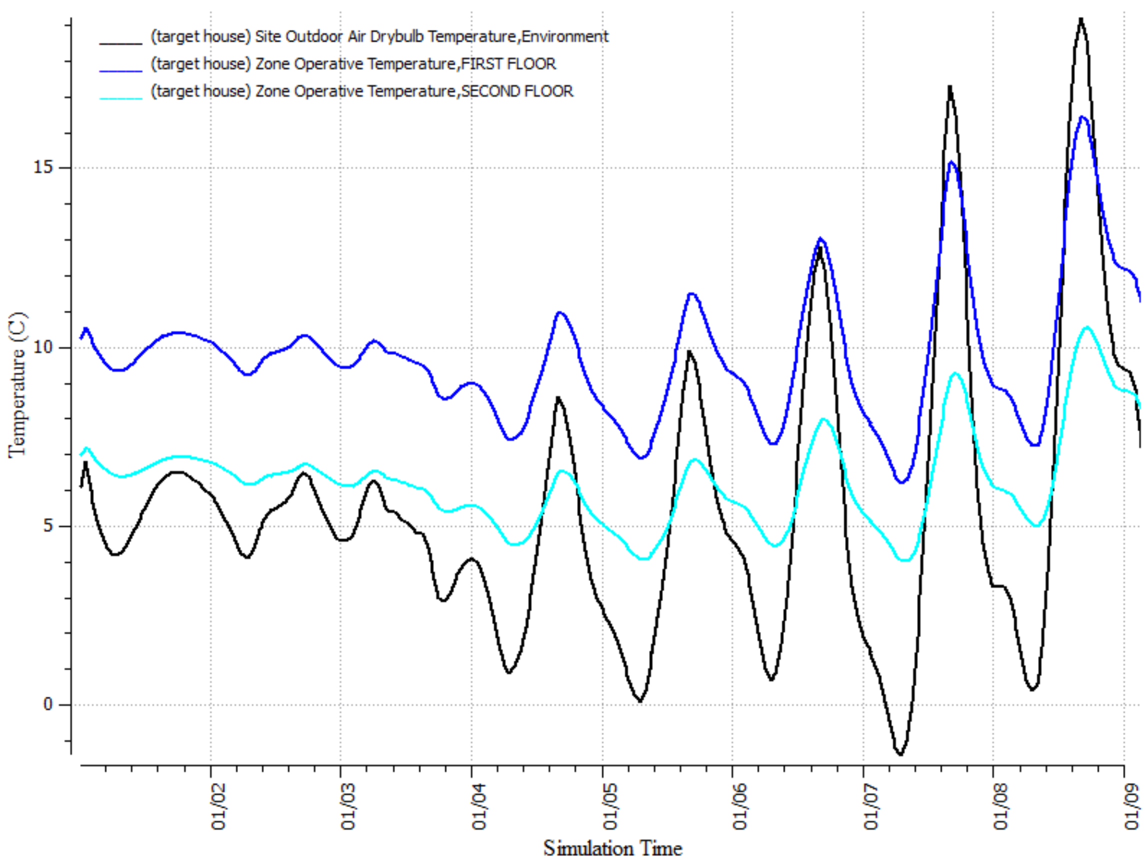

Figure 23: Target House Winter Typical Day Temperature.

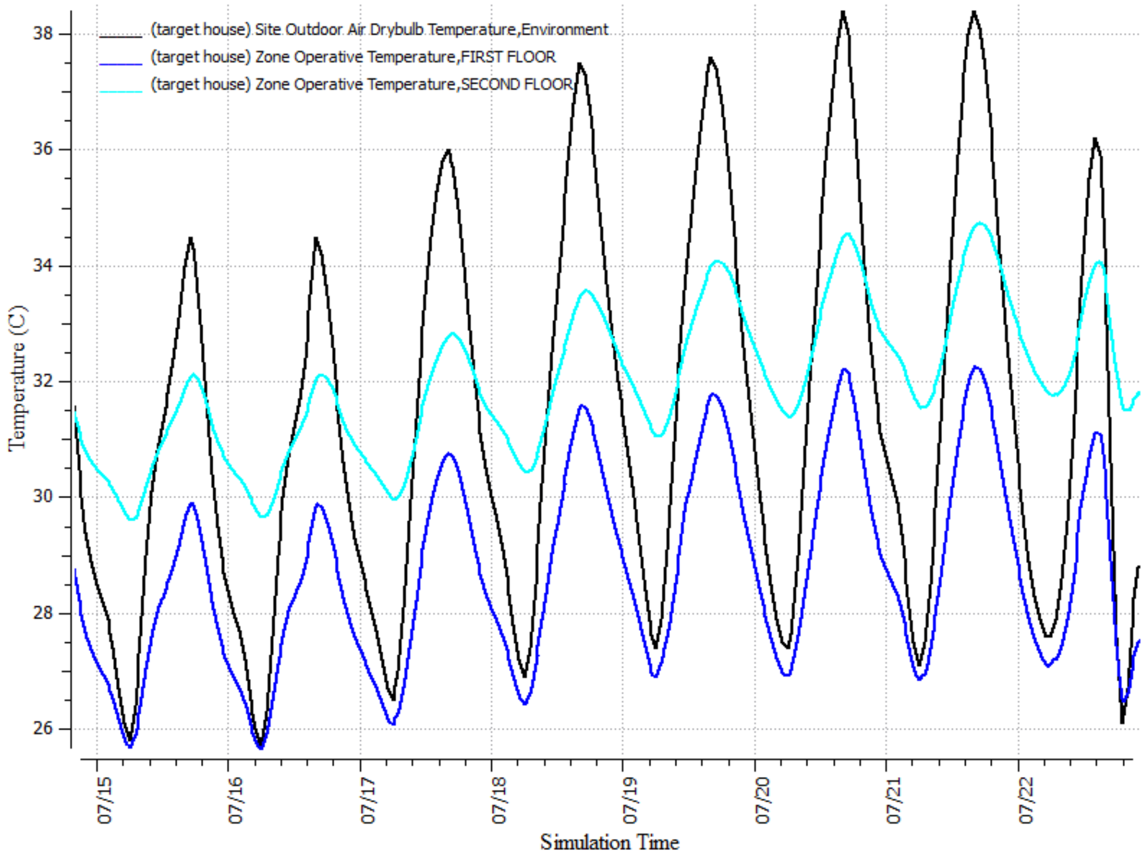

Figure 24: Target House Summer Typical Day Temperature.

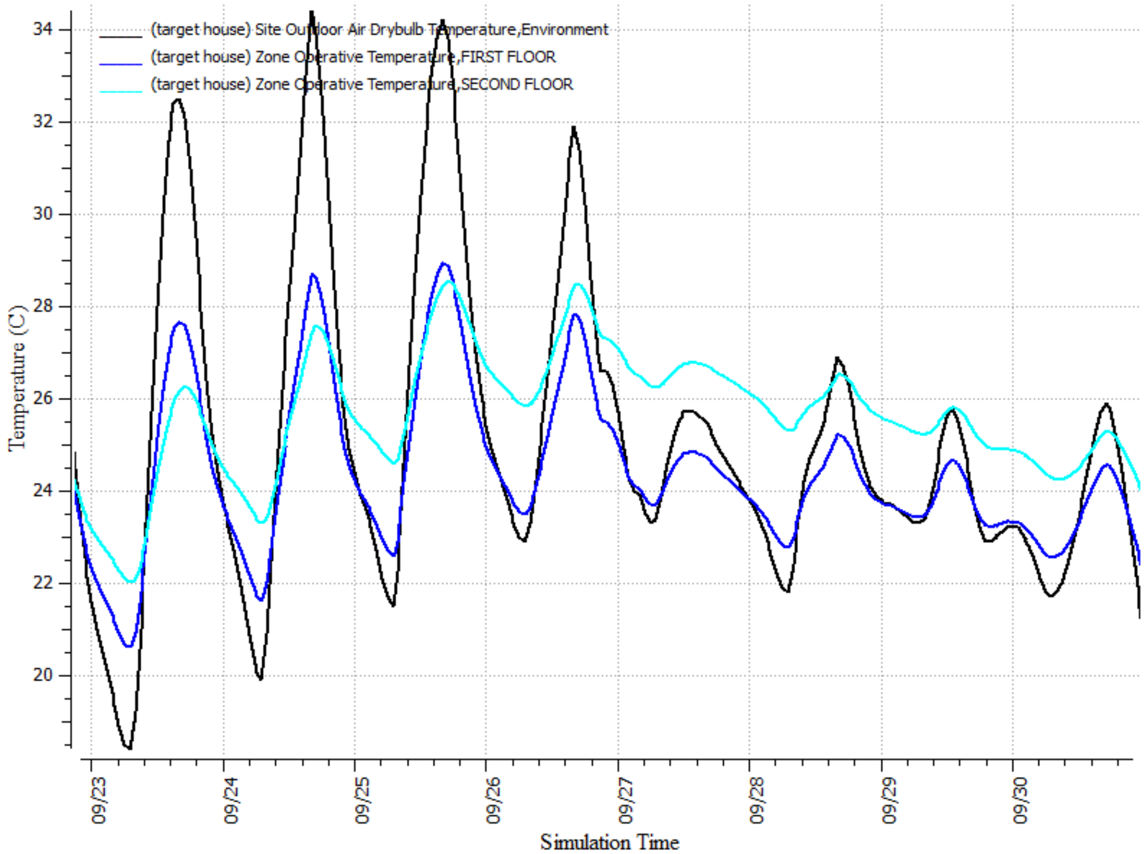

Figure 25: Target House Autumn Typical Day Temperature.

The simulation shows that the target house performs well in preventing too extreme indoor air temperature. However, in the typical days during wintertime, the indoor climate in first and second floor ranges between 5-15 °C, which is too cold for people who have adjusted to convenient modern life. During summer time, the situation is relatively better. Indoor temperature is kept between 26-30 °C in first floor and 29-32 °C in second floor, which also will be too hot. In old time, people had their own way to achieve thermal comfort in those extreme weathers. Like in the winter, they would use coal stoves to provide heat. In the hot summer, they would find a chilly part on first floor at daytime and go back to the second floor after sunset as the heat wave was disappearing. During autumn time, the indoor climate range is between 22-28 °C, which is comfortable. Base on this simulation, I would propose this building to be conditioned during winter and summer to adjust to modern life.

5.2.3 Indoor Relative Humidity

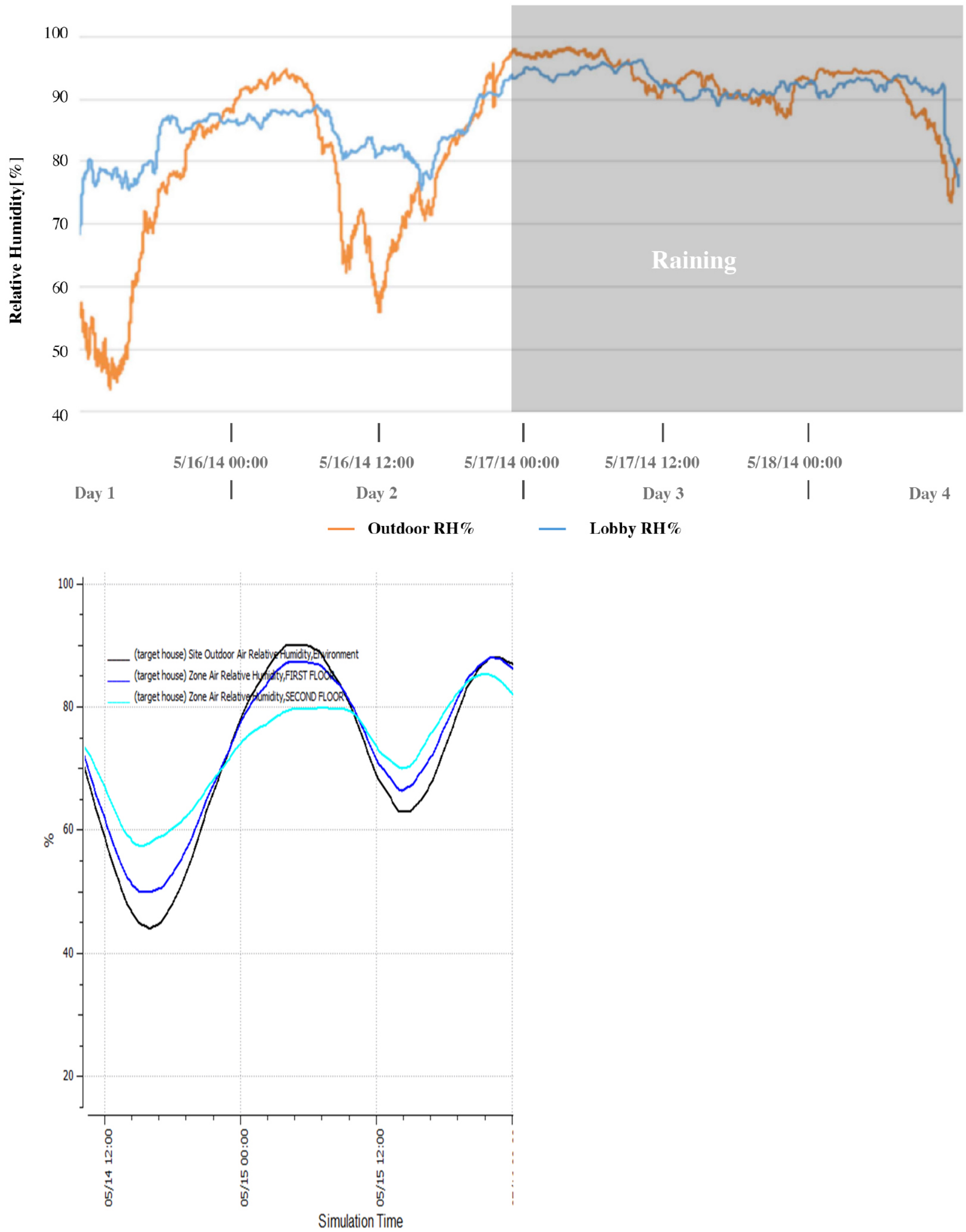

Figure 26: Comparison of Relative Humidity: Hobo Logger Documentation vs. EnergyPlus Simulation.

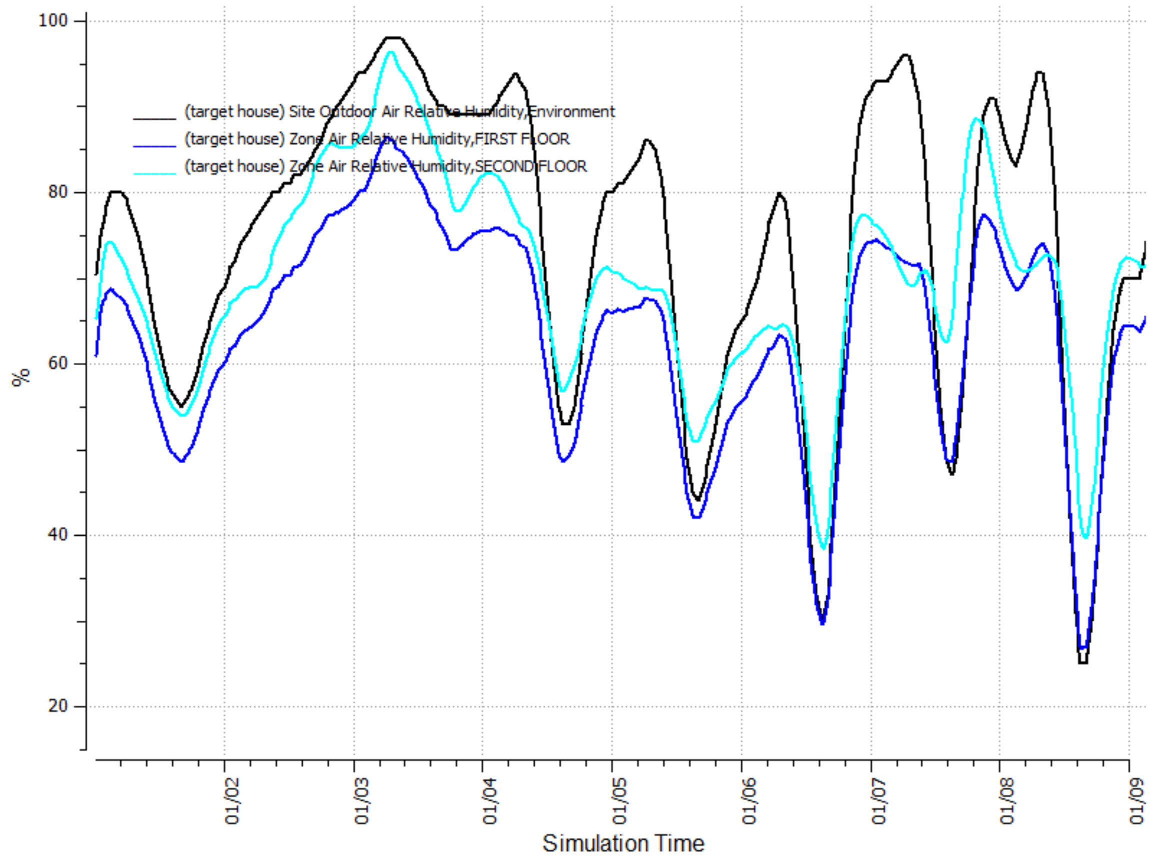

Figure 27: Target House Winter Typical Day Relative Humidity.

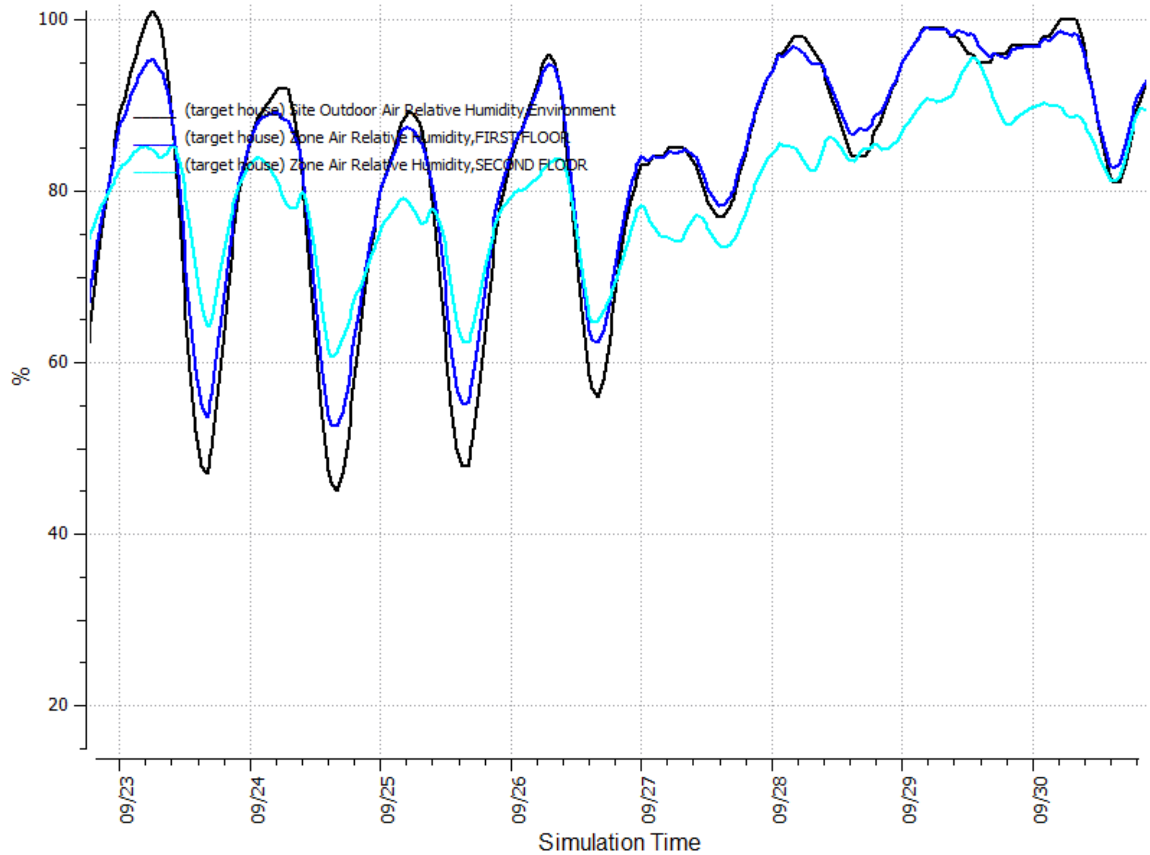

Figure 28: Target House Summer Typical Day Relative Humidity.

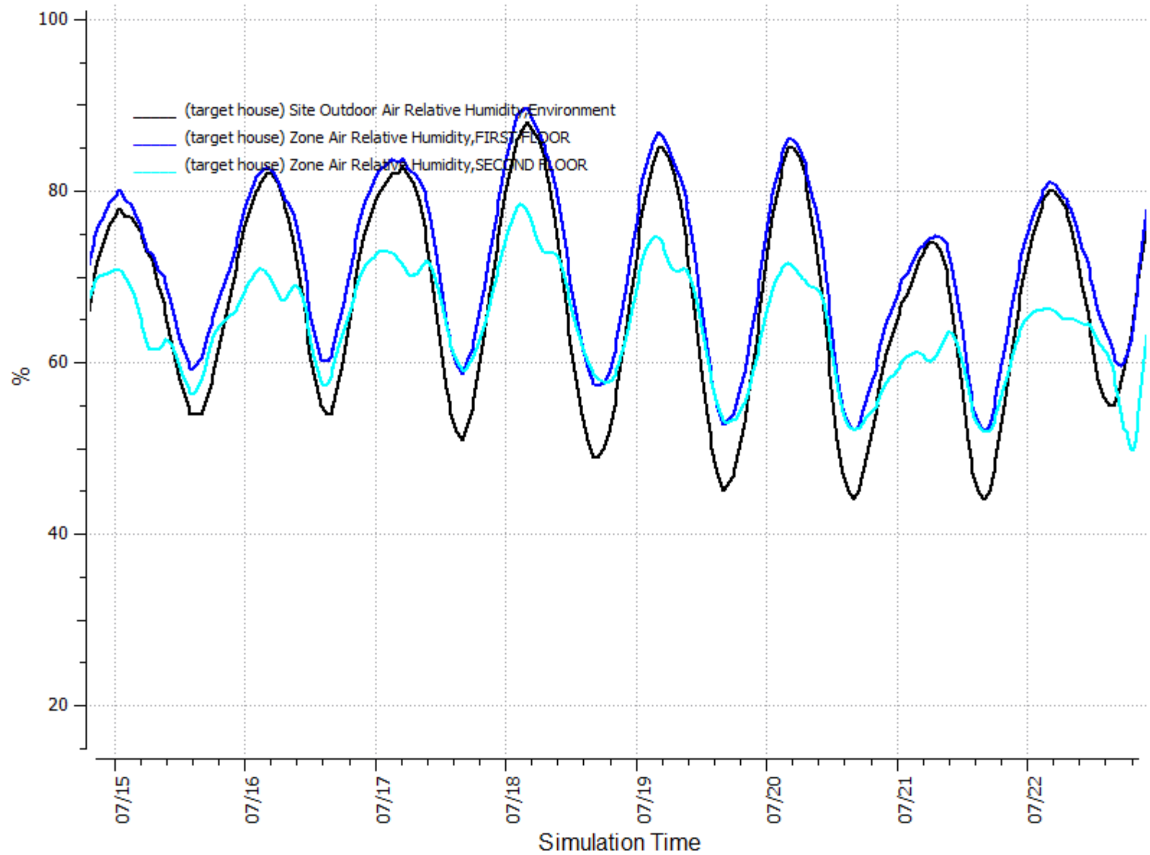

Figure 29: Target House Autumn Typical Day Relative Humidity.

In this humid climate, it is hard to dehumidify indoor air through passive strategies. Relative humidity range for comfort zone defined by Ashrae55(Ashrae 2004) is between 30-60%. However, human body response to different climate conditions by acclimatization and adaptation. People in the old time could use their adaptive capacity to get used to this humid climate. Nowadays, people are more spoiled by modern technology. But we can still minimize the dependence of mechanical systems through taking advantage of people's acclimatization and adaptation. Simulation data shows extreme humidity level (80-100%) during summer and winter, while a relatively acceptable humidity level during autumn (60%-80%). I would propose this building to be dehumidified in winter and summer.

5.3 Energy Simulation of Three Different Building Typology

This part compares three different building typologies of learning from vernacular. EnergyPlus model was used to simulate their heating and cooling loads.

Figure 30: Three Different Building Types.

5.3.1 Original Building

Original target house uses traditional materials and is very leaky. In this subtropical area with a moderate winter and hot summer climate, vernacular buildings didn't put much emphasis on keeping it supper tight. The infiltration rate in this house was about two air change per hour (ACH). This building is completely passive with no mechanical system inside. To compare the heating and cooling loads in this building, a simplified HVAC system was built on the second floor. As the first floor is completely open to the inner yard, it cannot be conditioned.

5.3.2 Modern Conventional Building

Figure 31: Hui Style Villa, Built in 2009.

Above is a Hui Style Villa, built in 2009, in Southeast of China. It mimics some of the vernacular building language like white lime plaster walls, grey roofs and even the very complex woodcarving decorations on the door and windows. However, if all of these decorations were removed from it, the only thing left would be a three floor's modern build box, which could be built anywhere in the world. This kind of modern conventional building is being built in great numbers in China every year. This phenomenon pushes us to ask: what's the essence of learning from Hui Style Buildings? It is commonly accepted by scholars in architecture area that this kind of buildings takes the wrong road of learning from vernacular.

An EnergyPlus model was built to simulate the heating and cooling loads of this building type. It uses modern building materials and techniques. Its infiltration rate is 0.5ACH. This building is conditioned all the time and has no inner yard.

5.3.3 Proposed Building on the Right Way of Learning from Vernacular

Based on the analysis of indoor climate of the target house, a new building type which combines the benefits of modern building and vernacular building is being proposed. This building inherits the same building typology as original building, with the same size of courtyard, the same amount of glazing and same openings. However, it uses modern sustainable building material and modern construction techniques as the modern conventional building, like a lower U-value and lower infiltration rate (0.5 ACH). Because of the extreme weather in this area during winter and summer, the first floor of this building was conditioned during these periods, while the second floor was conditioned all around the year. People can enjoy the beautiful outdoor climate during spring and autumn.

5.3.4 Construction of These 3 Buildings

	Original Building	U-Value(W/m²K)	Modern Conventional	U-Value (W/m²K)	Proposed	U-Value (W/m²K)
Exterior Wall:	Lime Plaster	1.65	Lime Plaster	0.31	Lime Plaster	0.31
	Brick fired clay		Insulation Board		Insulation Board	
	Lime Plaster		Concrete Block		Concrete Block	
			Lime Plaster		Lime Plaster	
Interior Wall:	Hard Wood	2.75	Masonry Wall	0.92	Masonry Wall	0.92
Exterior Roof:	Roof Tiles	1.45	Roof Tile	0.26	Roof Tile	0.26
	Wood Roof Truss		Insulation Board		Insulation Board	
			Wood Roof Truss		Wood Roof Truss	
Interior Floor:	Hard Wood		Wood Panel		Hard Wood	
			Precast Concrete Panel		Precast Concrete Panel	
Interior Ceiling	Wood Roof Truss		Wood Roof Truss		Wood Roof Truss	
Window	Wood Window		Double Glazing		Double Glazing	
Exterior Floor	Bluestone	1.56	Insulation Layer	0.17	Insulation Layer	0.17
			Concrete Block		Concrete Block	
			Wood Panel		Wood Panel	
Exterior Door	Hard Wood		Hard Wood		Hard Wood	
Interior Door	Hard Wood		Hard Wood		Hard Wood	

Table 3: Original Construction vs. New Construction.

	Infiltration Rate(ACH)
Original	2
Modern Conventional	0.5
Proposed	0.5

Table 4: Infiltration Rate of 3 Building Type.

	U-Factor	Solar Heat Gain Coefficient	Visible Transmittance
Wood (original)	0.90	0.01	0.01
Double Glazing	0.30	0.60	0.60

Table 5: Window Definition.

Figure3 presents the construction detail. Original building's external structure's U-values are much more lower than modern conventional building and proposed building. Also, the infiltration rate of the original house is much more higher than the other two. To control the variable factors in this simulation, modern conventional house and proposed house have the same construction set and same infiltration rate.

5.3.4 Heating and Cooling Loads of These 3 Buildings

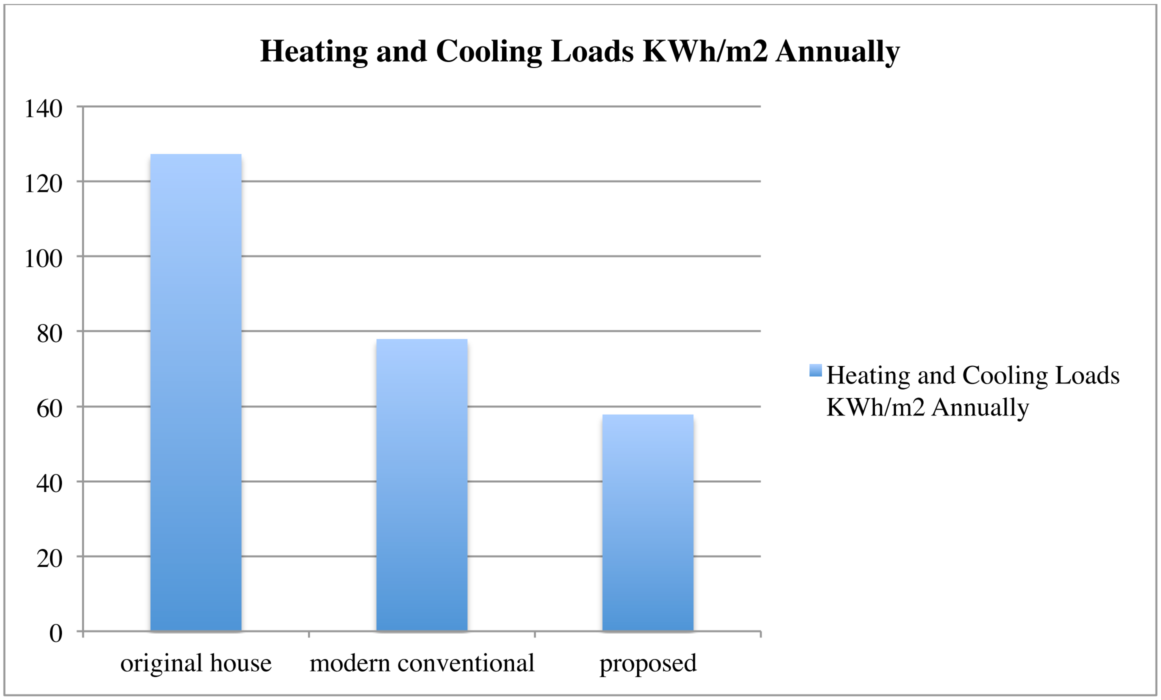

Figure 32: Heating and Cooling Loads of 3 Different Building Types.

	Heating and Cooling Loads KWh/m2 Annually
original house	127
modern conventional	78
Proposed	58

Table 6: Heating and Cooling Loads of 3 Different Building Types.

Simulation shows that proposed house has the lowest heating and cooling loads per square meters annually, which means it is the most energy efficient house among these three buildings. Original house has the worst performance because of the limitation of ancient building techniques. Simple construction with only traditional materials can no longer meet modern building standard. Modern conventional house and proposed house have the same construction set. The changing parameters between those two are building typology and conditioning schedule. This simulation proves the efficiency of vernacular building's climate adaptive building typology.

5.4 Conclusion

The material analysis of target house illustrates that although traditional materials are locally accessible at past, it doesn't mean that we can have the same choice today. High price, pollutant manufacturing process and unable to meet modern construction standard are all reasons for contemporary architects to make careful decision when they are learning from vernacular. Using the same material is the easiest way to keep the same sense of touch with vernacular buildings. But it is not the only way and has so many negative effects. Deep researches should be done before decisions are made.

In the second part, more and more architects realize it is important to make contemporary buildings have local identity, connect to local culture and history. Mimicking old building façade or decoration details doesn't take the right way of learning from vernacular. The essence of learning from vernacular should be its typology, orientation and urban context. They are all been modified through thousands of years and adapted to local climate.

Chapter 6: Ventilation Research

Hui Style Buildings have highly effective operable natural ventilation system, which is very beneficial for buildings' energy saving potential in such a subtropical climate. This chapter illustrates target house's natural ventilation strategies and tries to provide contemporary architects design inspirations for natural ventilation design.

6.1 Target House's Natural Ventilation Strategy

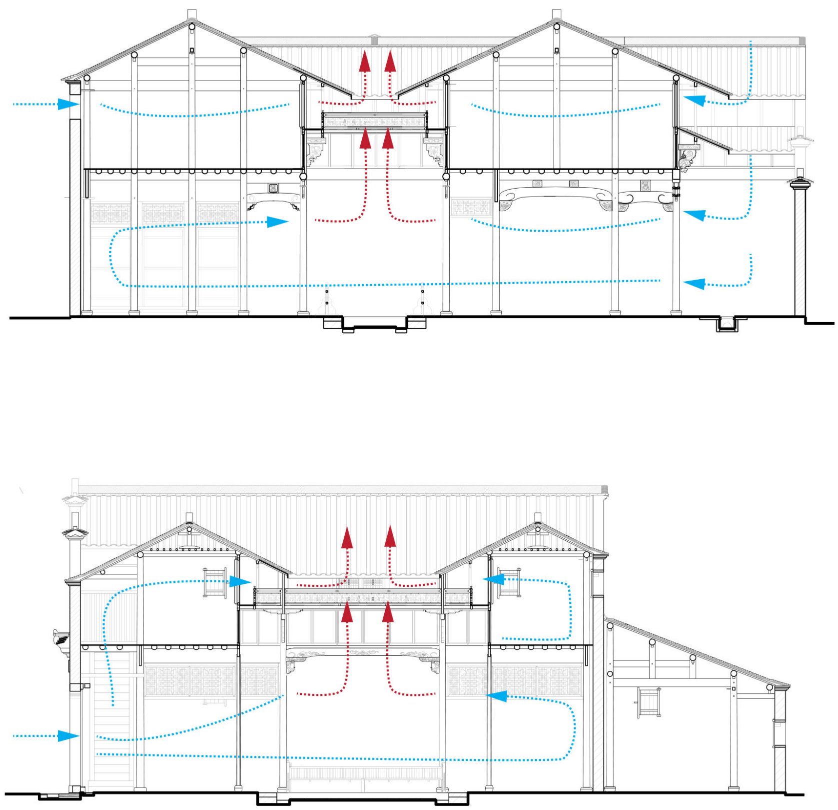

Figure 33: Natural Ventilation in Target House.

In this building, there are no walls facing courtyard. Fresh air coming from courtyard gets in and out freely. There is a large amount of operable wood window panels facing courtyard on the second floor. These window panels can be opened for natural ventilation when the outdoor climate is pleasant. Two courtyards makes cross ventilation possible although there are only a few windows facing outside.

6.2 Potentials for Natural Ventilation in this Climate

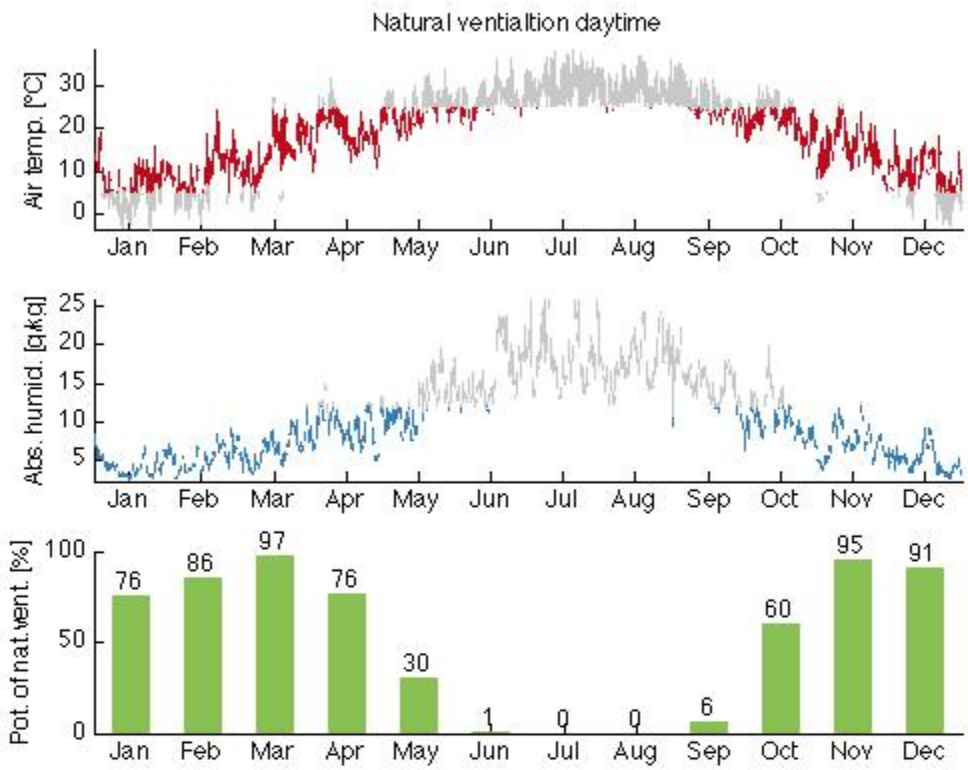

Figure34: Potentials of Natural Ventilation in Target House by ClimateTool.

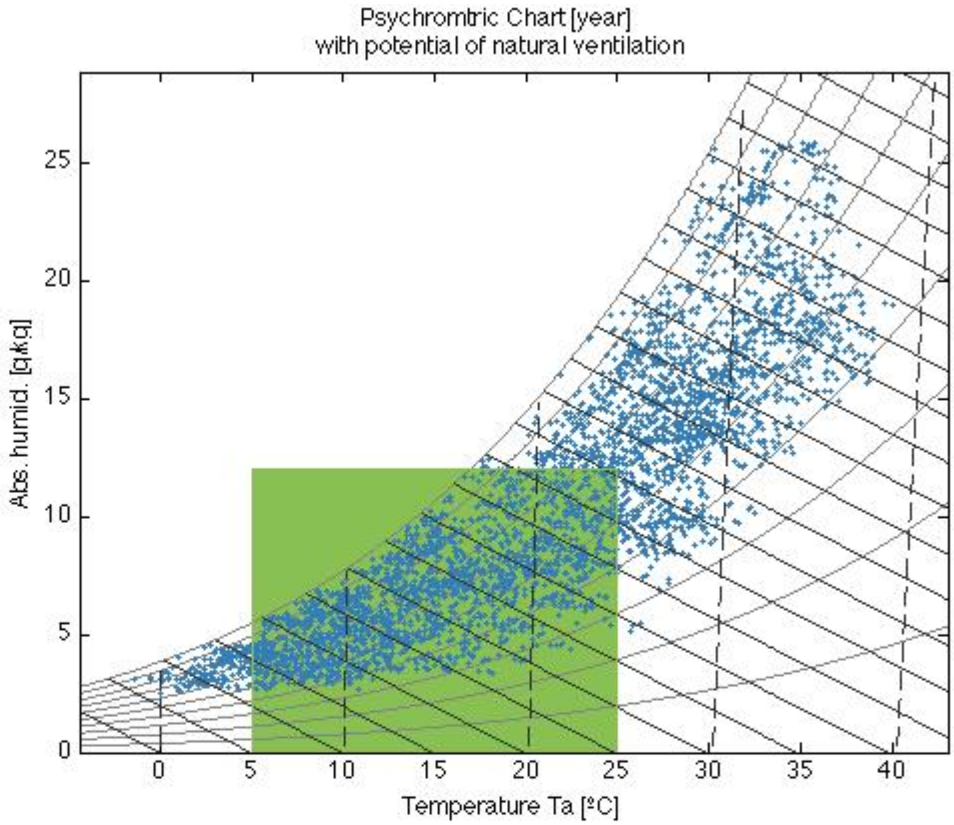

Figure 35: Potentials of Natural Ventilation in Target House by ClimateTool.

Figure 34 and 35 are generated by using ClimateTool. One can tell the potential of the natural ventilation in target house, which was decided by outdoor climate. From October to April, the potential of natural ventilation at this location is quite high. During March, November and December, the potentials are more than 90 percent. Those diagrams suggest that we should take advantage of natural ventilation for buildings in this area.

6.3 Conclusion

Target house performs well in introducing natural ventilation. Ventilation elements in this building such as those two small courtyards and all those large openings facing inside can be considered for today’s contemporary buildings. Target house has a compact shape to reduce heat gains and large windows for natural ventilation as well.

Chapter 7: Daylight Research

"We delight in the mere sight of the delicate glow of fading rays clinging to the surface of a dusky wall, there to live out what little life remains to them. We never tire of the sight, for to us this pale glow and these dim shadows far surpass any ornament."

------In Praise of Shadows(Tanizaki 2001)

7.1 INTRODUCTION

Le Corbusier once identified the importance of light in architecture: "architecture is the masterly, correct and magnificent play of volumes brought together in light..."(Corbusier 1931) Daylight can replace artificial light and reduce light energy usage. In ancient time, daylight was the primary source of lighting in buildings. Because of that, vernacular buildings are more sensitive of the power and meaning of natural light. This chapter thoroughly illustrates the natural illumination in target house and its daylight design strategies. The objective of this chapter is to give contemporary architects a fully understanding of vernacular buildings' illuminance level and how it responds to daylight.

Figure 36: Shadows in Hui Style House.

I had two periods of experience of living in Hui Style Buildings. Both of them happed during summertime. I still remember that daylight was not evenly distributed in this kind of buildings. Some rooms were bright, while it's dark in other rooms. Experiences in this house are very different from modern residential buildings. You can experience the extreme confliction between brightness and darkness. One may raise questions that can this building offer sufficient daylight for modern life? What are the pros and cons of brightness and darkness confliction?

7.2 Illuminance Map

EnergyPlus was used to simulate illuminance map in target house. Four illuminance maps were built in EnergyPlus model: illuminance map of west, first floor; illuminance map of west, second floor; illuminance map of east, first floor; illuminance map of east, second floor. In this residential house, illumination between 100-1100 lux will be an effective range for most of the activities happening in this building. Illumination below 100 lux will not be enough for even simple tasks, while illumination above 1100 may cause visual discomfort. The output range of illuminance map of this building was set as 100-1100 lux.

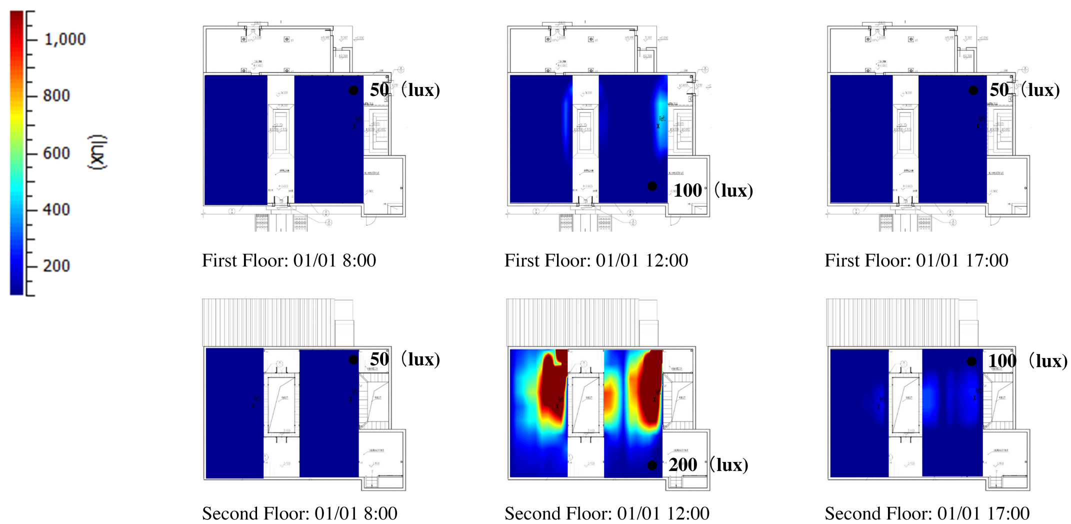

Figure 37: Illuminance Map on Date 01/01.

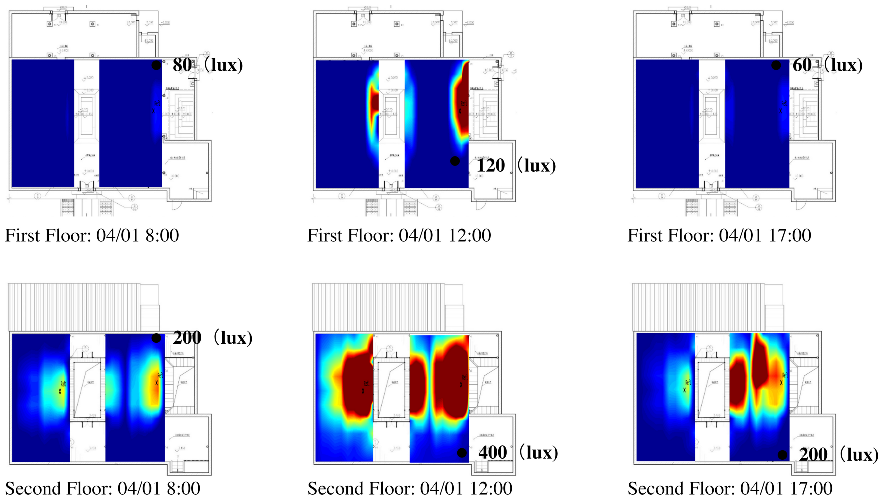

Figure 38: Illuminance Map on Date 04/01.

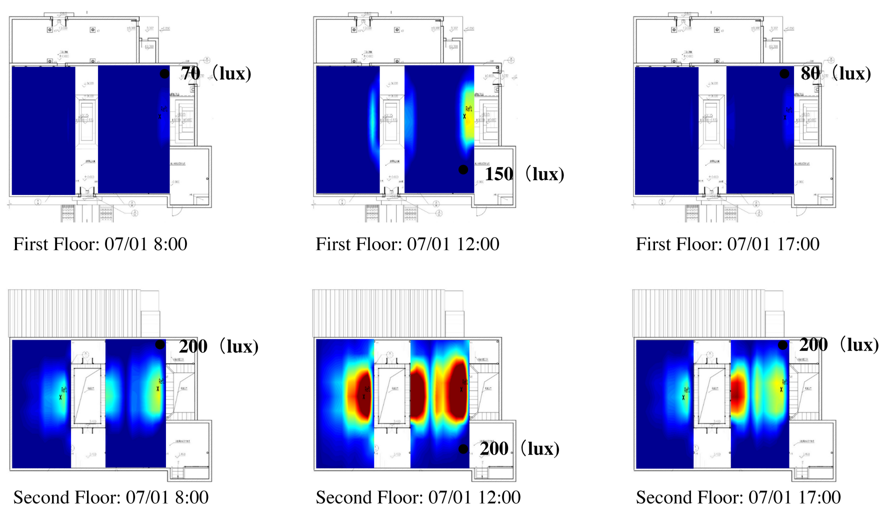

Figure 39: Illuminance Map on Date 07/01.

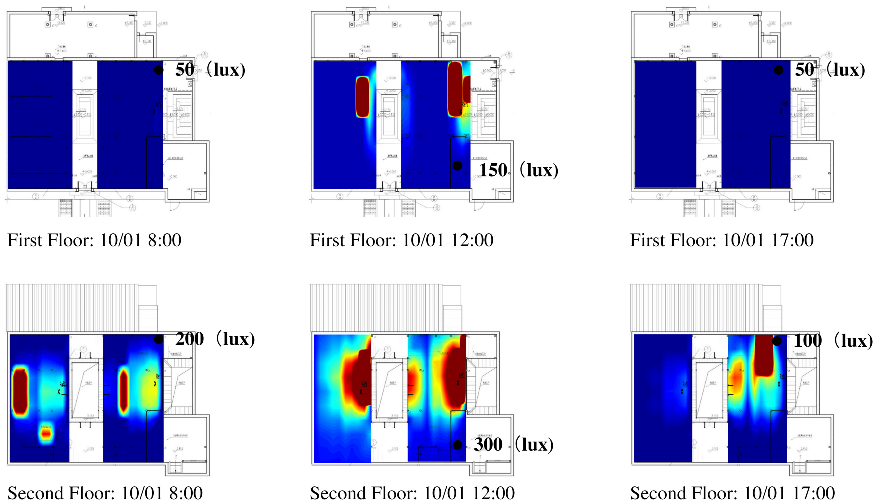

Figure 40: Illuminance Map on Date 10/01.

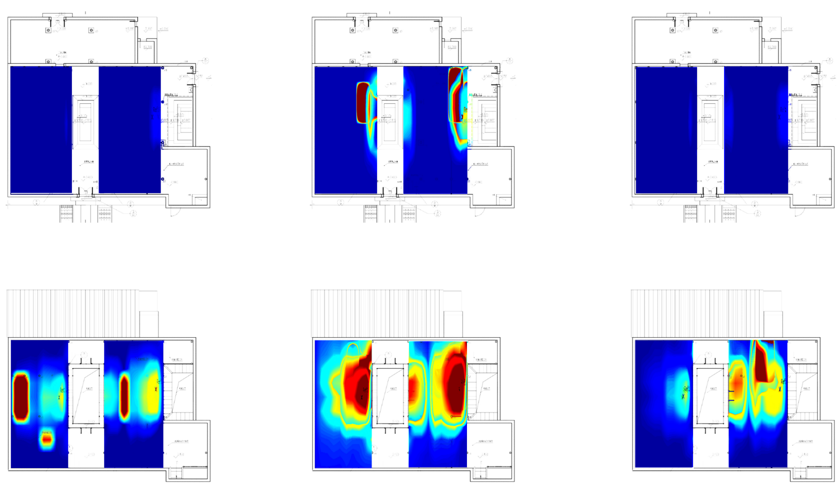

Figure 41: Bended Illuminance Map.

The blend mode "brighter" was used to combine the illuminance map of four seasons together. This diagram shows the highest illumination level this building can achieve. Simulation results match with the observation that there are strong confliction of brightness and darkness in this building. The illuminance level of the first floor is comparatively low, while some rooms on the second floor are very bright. However, although illuminance level in first floor is relatively low, the lowest level in early morning and late afternoon in the winter is still around 50 lux, which is not extreme darkness. I can still remember the days I lived in this kind of buildings. Below is a narrative to describe it:

"In the early summer morning, I was waked up by the sun. I went to the kitchen to make a cup of tea. The staircase was comparatively dark. I adjusted my eyes to get used to it. The ground in the staircase was checkered with sunlight and shade. The kitchen was quite bright. I didn't need any electrical light in this wonderful morning to make a cup of tea. I took the tea to my living room on the first floor. It was dark and quite. I laid on the sofa and it was like a short meditation time. I finished the tea, went upstairs to my bedroom to do some computer work. It felt like going back to the bright world."

7.3 Daylight Control Strategies in Target House

Daylight control strategies used in target house is analyzed in this section. This helps to explain why some parts of this building are bright while others are dark.

7.3.1 Building Form and Daylight Penetration

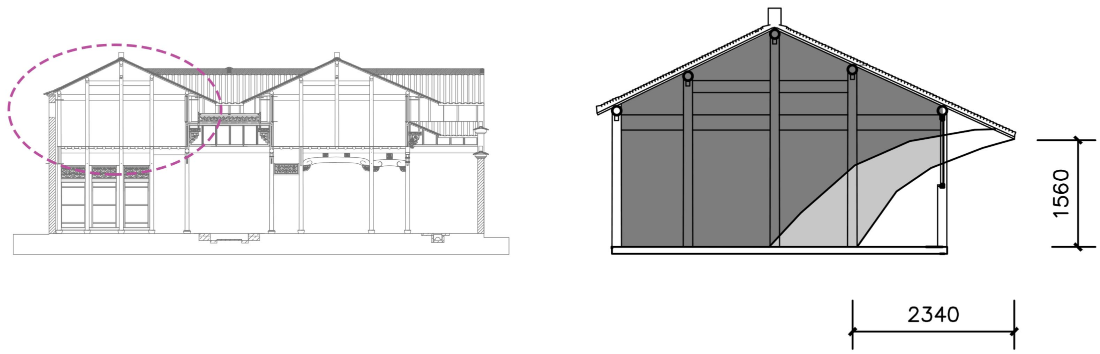

Figure 42: Depth of Adequate Daylight Penetration.

There is a direct relationship between the height of the window head and the depth of daylight penetration. Diagram above shows that only about 25% percent of the space can be reached by the adequate daylight on the second floor, while the rest parts are extremely dark. However, as there are long window band facing courtyard in every room on the second floor, spaces close to the windows are quite bright.

7.3.2 Obstructions

Outside obstructions reduce day lighting potential. As most of the window openings are facing towards inner yard, obstructions, which influence indoor daylight, are this building itself. The dimension of the courtyard plays an important role in day lighting potential. This building has small courtyards. Due to this reason, only a small amount of daylight reaches first floor.

7.3.3 Exterior Shading

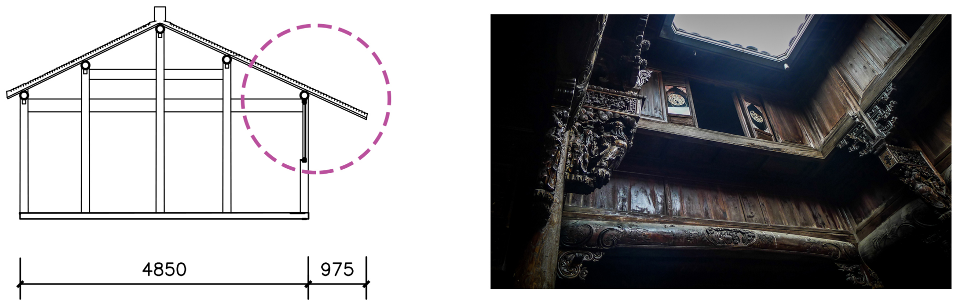

Figure 43: Exterior Shading.

Overhang shading outside inner yard windows spreads out as much as 0.975 meter. This exterior shading effectively reduce the daylight penetrate into this building.

7.3.4 Windows Facing Different Direction

Windows and openings in this house faces towards four different directions. As the sun arises and falls down, different parts of this building will be lighted.

7.4 Possibilities for a New Floor Plan

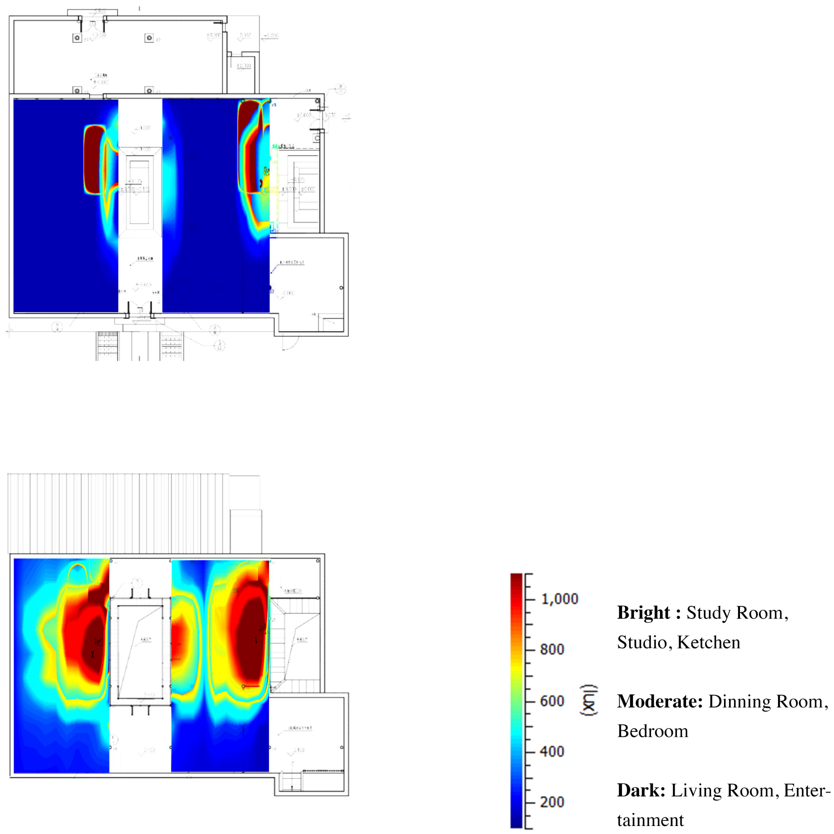

Figure 44: Possibilities of Floor Plan in Target House According to Daylight Distribution: Fist Floor(above), Second Floor(below).

We enjoy the special experience due to the conflictions of brightness and darkness in this building. We also avoid the inconveniences introduced due to the low illuminance level in some parts of this building. Living room for entertainment like movies or video games can be placed in the darkest part of the house. Rooms which need more light such as study room, can be placed on the second floor.

Chapter 8: Courtyard Ratio Research

8.1 Building's Energy Performance with Different Courtyard Ratios

Courtyard is an important component in Hui Style Buildings. It allows adequate illumination and ventilation, while restricting possible rain and draughts. The slope roofs above the courtyard are so designed as to collect maximum amount of rainwater, as the collection of rain is symbolic for their accumulation of wealth. In this target house, there are two courtyards. The ratio of courtyards area to the building's first floor area is 17.5%. After all previous analysis, I cannot stop thinking why the courtyards in all Hui Style Buildings are relatively small? What will happen if they have a bigger courtyard? What's the relationship between courtyard ratio and the local climate?

Three EnergyPlus models was built and simulated for this purpose. In this energy modeling process, all parameters other than the courtyard size are fixed in all those three models. The ratios of courtyard area are as follows:

	First Floor Area(m2)	*Courtyard A(m2)*	*Courtyard B(m2)*	*Courtyard Area Ratio (%)*
Original	174	20	17	17.5
Model 1	162.5	26	22.5	23
Model 2	185.7	13.7	11.6	12

Table 5: Courtyard Area Ratio of Three EnergyPlus Model.

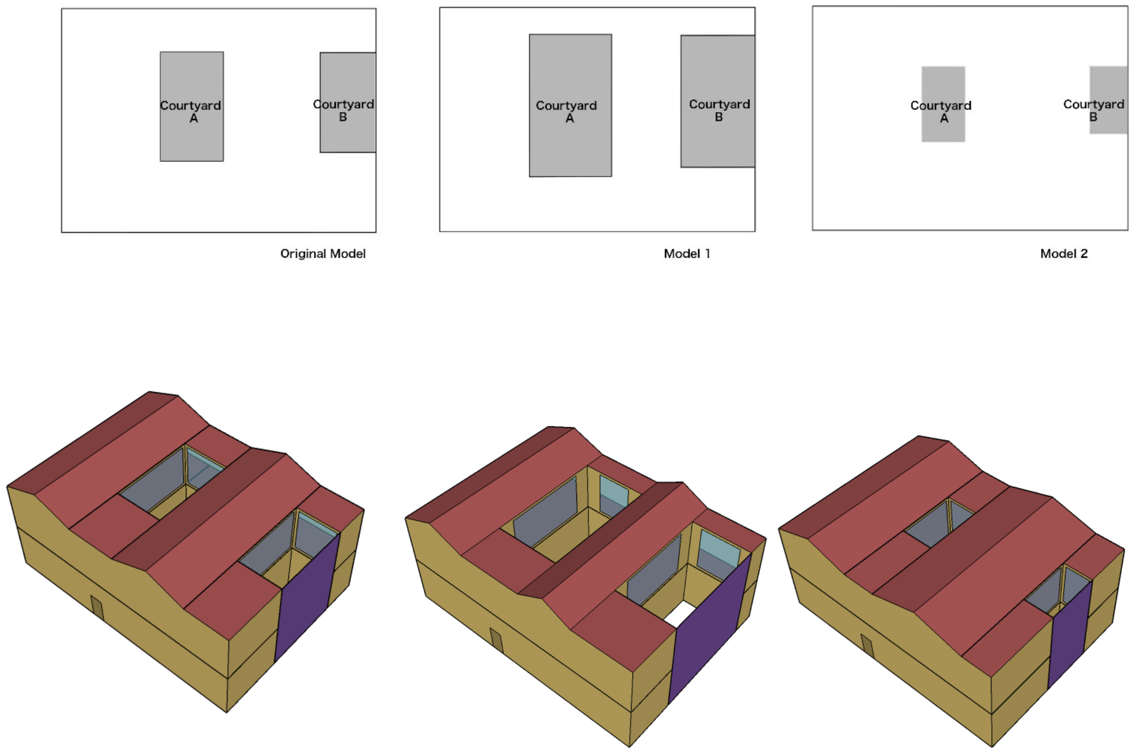

Figure 45: 3 EnergyPlus Models with Different Courtyard Ratio.

8.2 SIMULATION RESULT

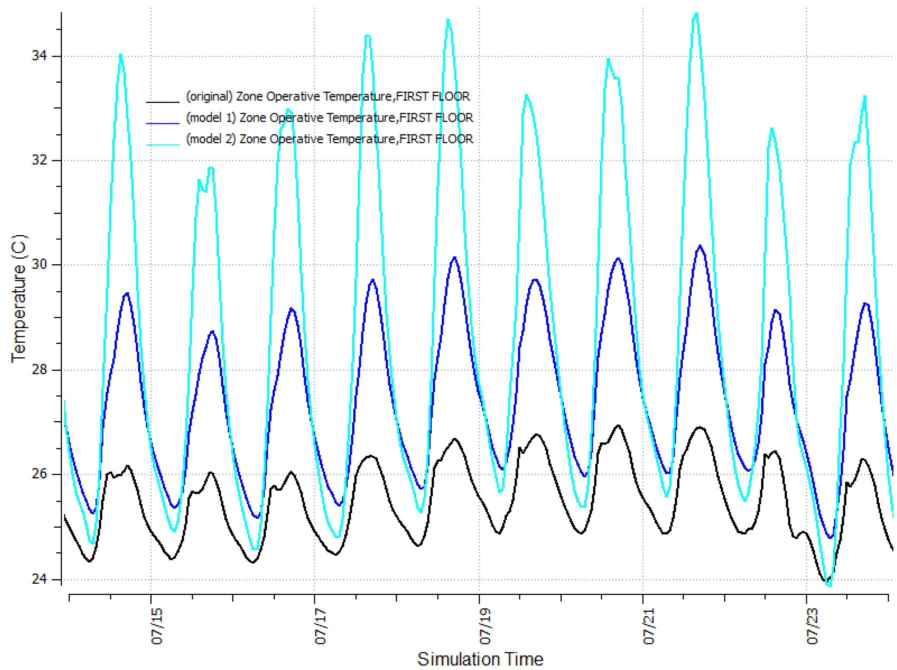

Figure 46: Summer Typical Day Operative Temp. 1st Floor.

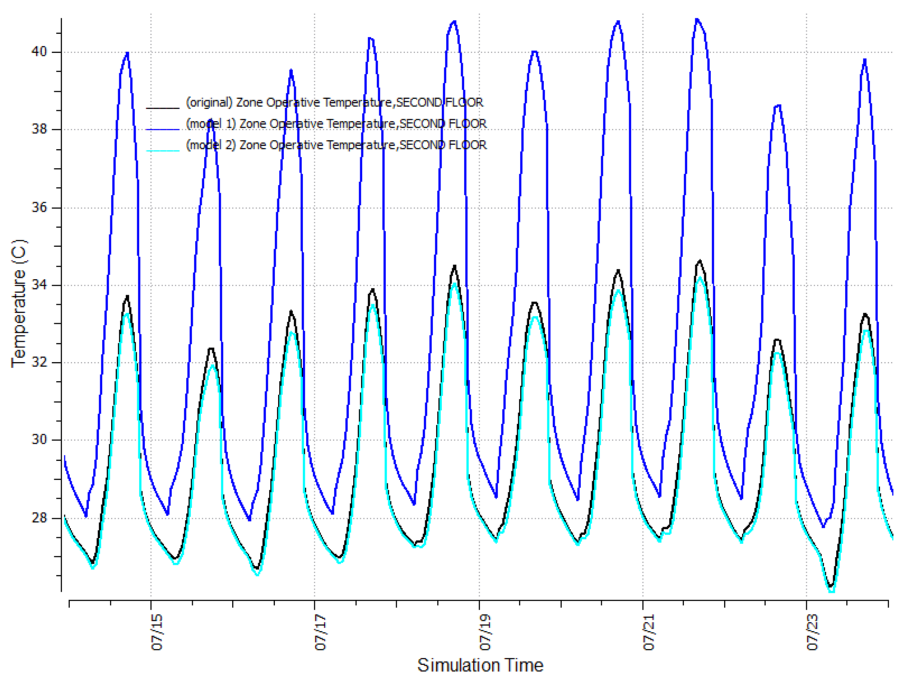

Figure 47: Summer Typical Day Operative Temp, 2nd Floor.

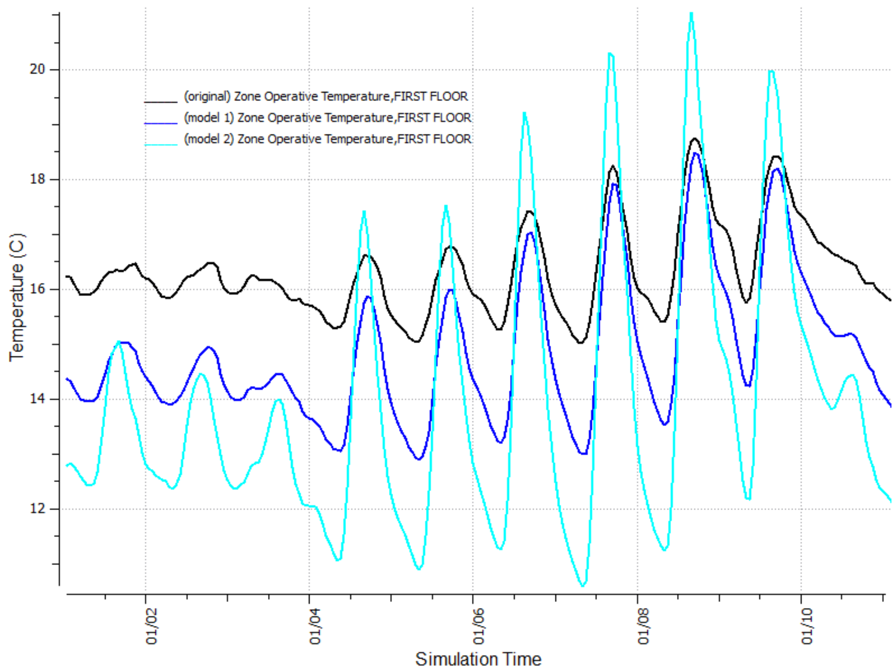

Figure 48: Winter Typical Day Operative Temp,. 1st F.

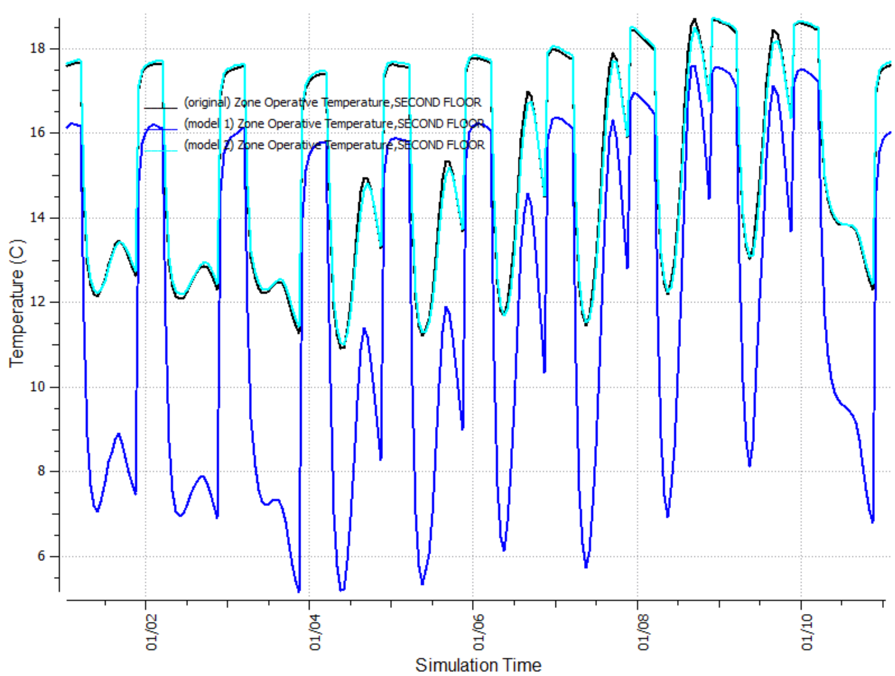

Figure 49: Winter Typical Day Operative Temp, 2nd F.

Diagrams above show the indoor temperatures in these 3 models. Obviously, the original model performs the best by keeping a relatively comfortable indoor temperature.

	Zone Ideal Loads Supply Air Total Heating Energy [KW•h/m2](Annual)	Zone Ideal Loads Supply Air Total Cooling Energy [kW•h/m2] (Annual)	Zone Ideal Loads Total Energy [kW•h/m2] (Annual)
Original Model	52.94	9.86	62.80
Model 1	68.15	11.77	79.92
Model 2	55.89	9.70	65.59

Table 7: Heating and Cooling Loads of Three Buildings with Different Courtyard Ratio.

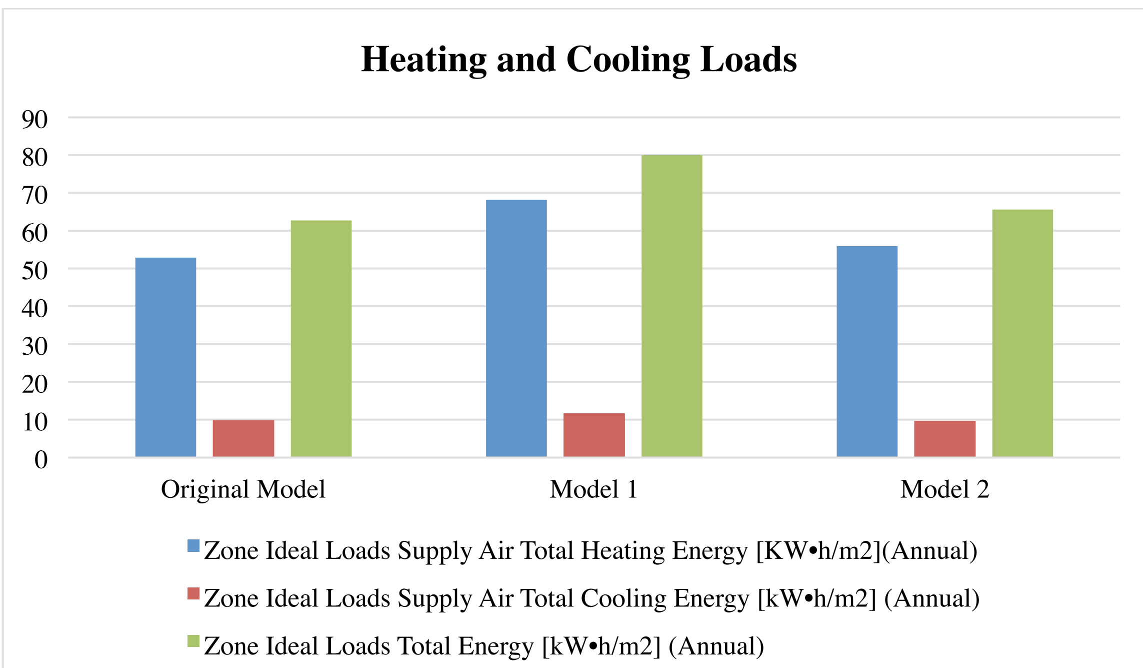

Figure 50: Heating and Cooling Loads of Three Buildings with Different Courtyard Ratio.

Simulation results show that the original building also has a relatively low heating and cooling loads among three scenarios.

8.3 Conclusions and Suggestions for Contemporary Architects

Courtyard typology in Hui Style Buildings is quite unique among all vernacular buildings in China. The courtyard of Hui Style Building is relatively small. This kind of small courtyard helps to protect vernacular building from gaining too much heat during summer, while allows solar radiation to get into the building during mild winter. For contemporary architects, it is important to be aware of the courtyard ratio in learning from Hui Style Buildings.

Chapter 9: Real World Practice on the Way of Learning from Vernacular Hui Style Buildings

9.1 SUCCESSFUL REAL WORLD PRACTICE OF LEARNING FROM VERNACULAR

9.1.1 Xiang Shan Campus

Figure 51: Library Building in Xiangshan Campus.

Wang Shu, the first Chinese citizen who has ever won the Pritzker Prize, is a master in using traditional materials to reflect history. In one of his famous projects, Xiangshan Campus, he salvaged over two million tiles from demolished traditional houses to cover the roof of campus buildings. Buildings in this campus have very modernized simple shape. However, with recycled traditional materials and detail building techniques from the past, this newly built campus gave people a strong sense of history.

9.1.2 Suzhou Museum

Figure 52: New Suzhou Museum.

The new Suzhou museum was designed by I.M Pei Architect with Pei Partnership Architect is located in the northeast of Suzhou, a beautiful historical city in YRD, China. The design of this museum takes its cues from the rich vocabulary of Hui Style Buildings, with whitewashed plaster walls, dark grey clay tile roofs. However, these basic elements have been interpreted and synthesized into a new language and order.

9.2 Failed Real World Practice of Learning from Vernacular

9.2.1 A Hui Style Villa in Suzhou

Figure 53:   Hui Style Villa, Built in 2009.

This villa has been talked a lot before. It simply mimic the vocabulary used in Hui Style Buildings without deep consideration. These newly built buildings have the identical white walls, dark grey roofs and even the same complex wood decorations. However, those designers never realize the importance of the dimension of house. There is even no any courtyard in those buildings.

9.2.2 The Fifth Garden

Figure 54:   The Fifth Garden.

The fifth garden is a very famous commercial real estate project in China. It is inspired by Hui Style Buildings. Similar to the Suzhou Museum, we can tell the spirit and cultural heritage from Hui Style Buildings in this project but we can still easily tell that it is a newly built contemporary building. Designers used modern materials and construction techniques smartly to reveal the sense of touch from the history. Spaces here recalls visitors' memory from the past. This project is in Shengzheng, a city in Southern China. Shengzheng has a hot and humid climate and a very different vernacular building style there. One of the most important reasons that we should learn from vernacular buildings is that most of them are climate adaptive and make the maximum use of local resources. Although the design of this building is successful, ignoring the outside conditions and choose a vernacular building typology from a different location makes this project superficial.

9.3 CONCLUSION

The ancient wisdom in target house is shown in this research. They are adapted to the local climate and use all the local recourses. After all the analysis, we may go back to the original questions: "how to become modern and to return to sources; how to revive an old, dormant civilization and take part in universal civilization" (Frampton 1993). In my opinion, well-designed buildings, which find their inspirations from vernacular, can recall people's memory of local and people can tell where this building comes from. The essence of learning from vernacular should be: sense of touch, climate adaptive strategies, urban context and typology.

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